Study on water management at household level in Kathmandu valley, Nepal

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Abstract

Water is the essential resource for survival. However, residents of Kathmandu valley has been suffering from water shortage, since the water supply utility of Kathmandu valley has not been able to meet water demands of growing population. Households have been using multiple water supply sources of varying characteristics. Limited availability of good quality water for consumption has become a major concern. The government's effort to improve water supply has not been fruitful yet. In this context, there is need to identify suitable measures to improve access and manage available water supply sources and promote efficient use of those sources.

The first objective of this study was to examine characteristics of available water supply sources and their uses and to analyze association between socio-economic characteristics of households and uses of their water supply sources. Household interviews were conducted for 217 households in piped water service area of Kathmandu valley. The respondents were interviewed about their socio-economic characteristics, water supply sources, purposes *etc*. Due to intermittent piped water supply, the majority of households used multiple water supply sources. Aesthetic water qualities of water supply sources were found to influence the uses of water supply sources. Bottled water and public standpipe was used because it was believed to be of better quality than other water supply sources. Private piped water connection, private well and tankers were chosen because they were convenient to access, while community sources were available for free. The selection of water supply sources was found to vary for dry and wet seasons. The selection of water sources was found to be complex, since accessibility, price, quality and reliability of these sources varied. Monthly income, family size and number of occupants were found to influence selection of water supply sources. Similarly, distance of outdoor source from the residence of the households influenced selection of the outdoor sources during wet season.

The next objective was to quantify total amount of water consumption and amount of water consumed for different activities and to analyze association between socio-economic characteristics of households and amount of water consumption for potable and non-potable uses. Only 147 households were selected for estimating total amount of water consumption and to analyze factors influencing water consumption. For quantifying amount of water consumption for different activities, 32 households were selected. Households were asked to record amount of water consumption for each activity for seven consecutive days using utensils and sizes of utensils were measured. Average total water consumption of households in Kathmandu valley was 32.3±11.1 L/cap/day. Low frequency of bathing and adoption of water conservation measures were found to be major reasons for low water consumption of households in Kathmandu valley. Water consumption of households depending on private well and tanker was statistically different than those using private pipe connection or community water supply sources at a significant level. Monthly income and family size were found to influence amount of water consumed for potable as well as non-potable purposes. Number of elder members in a household and uses of bottled water were found to influence amount of water for potable use, while frequency of bathing and water use behavior of household were found to influence amount of water for non-potable purposes.

The third objective of this study was to understand microbial water quality at supply points of the water supply sources and points of uses and also estimate annual exposure of different consumption patterns to fecal bacteria. The water samples were collected from inlet and outlet of 8 water treatment plants. The samples of distributed water from each water treatment plant were collected at tap of households. The water samples from supply points of household's water supply sources were collected and also from point of uses such as water storage tanks, household's treatment system, bottles for storing treated water. The number of total coliform and *E. coli* in water samples was counted using membrane filtration method. Total coliform and *E. coli* were not detected at the outlet of water treatment plant but detected in tap of piped water, which shows contamination during water distribution process. Total coliform and *E. coli* counts for samples collected from bottled water, piped water and private suppliers were statistically different than those of wells and stone spouts at significant level. Wells and stone spouts were more contaminated than other water supply sources. *E. coli* count for samples collected from storage tanks were higher than those of supply points, while *E. coli* count for samples from household's water treatment system was lower than in supply point and storage tanks. However, contamination was detected in samples collected in bottles used for storing treated water. Microbial exposure was higher for households using stone spout for potable and non-potable uses.

The last objective of this study is to understand household's coping measures and factors influencing selection of those measures. Further, to quantitatively estimate the potential of gray water use and rainwater harvesting for improving water availability for non-potable uses across different income groups. The socio-economic information collected from 217 households and additional information on coping measures were used for this objective. Households with shorter periods of piped water supply tended to have a larger number of water supply sources to cope with water shortages. Household income was found to be a major factor influencing the selection of coping measures. To cope with water scarcity, the low-income group reduced their water consumption for bathing and laundry while maintaining their consumption for more essential activities such as hygiene and cooking. The study suggested that a 10,000-L water-storage tank would be sufficient to meet the minimum requirement (50.0 L/cap/day) over a year if rainwater harvesting could be practiced in addition to gray water use and piped water supply.

Keywords

Households, water supply sources, water consumption, water management, microbial contamination

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Chapter 1

Introduction

1.1 Research Background

Water is the essential resources for survival. In recent years, trend of water consumption has been increasing continuously. Limited availability of water for consumption is the major concern. Hence, there is need to efficiently use available water resources. Population growth and economic development are major causes for the increase of water consumption. Agriculture accounts for 80% of total water consumption in Asian region; however due to increase of industrial and domestic water demand, the management of water resources in urban areas will be more vital. Inappropriate or insufficient management of water resources have been widely recognized as the major reasons for water crisis in urban cities.

Similar to many other developing countries, Nepal faces plethora of problems regarding drinking water quality and availability. People have been exposed to severe health threats resulting from water contamination by sewage, agriculture and industry (Warner *et al*., 2007). Kathmandu valley is the urban center of Nepal and has been witnessing rapid increase in population. The proportion of residential area in Kathmandu valley has increased from 2.8% in 1967 to 12.6% in 2000 (Thapa *et al*., 2009). **Figure** 1.1 shows the land use cover map of Kathmandu valley in 2005. The current water supply utility of Kathmandu valley has not been able to expand its service area in the same pace as population growth (ADB, 2003). Water demand is estimated to be 320,000 m^3/day (KUKL, 2008); but the utility supplies only 101,000 m^3/day during dry season, and during wet season it supplies 137,200 m^3/day. Due to intermittent and insufficient piped water supply, households have been depending on alternative water supply sources such as vendor, well. Due to lack of proper management, groundwater extraction rate has exceeded its recharge rate (Pandey *et al*., 2010). Most of the previous studies in Kathmandu valley have focused on surface water and ground water quality (Warner *et al*., 2007; Chapagain *et al*., 2010); but there is lack of studies on water supply and consumption at household level.

With an aim to improve and expand the coverage of piped water supply services in Kathmandu valley, the government of Nepal undertook a project to import 170,000 m^3 per day of water from a neighboring watershed area; however, even after completion of the project, water shortage is expected to persist. Hence, households will be required to use

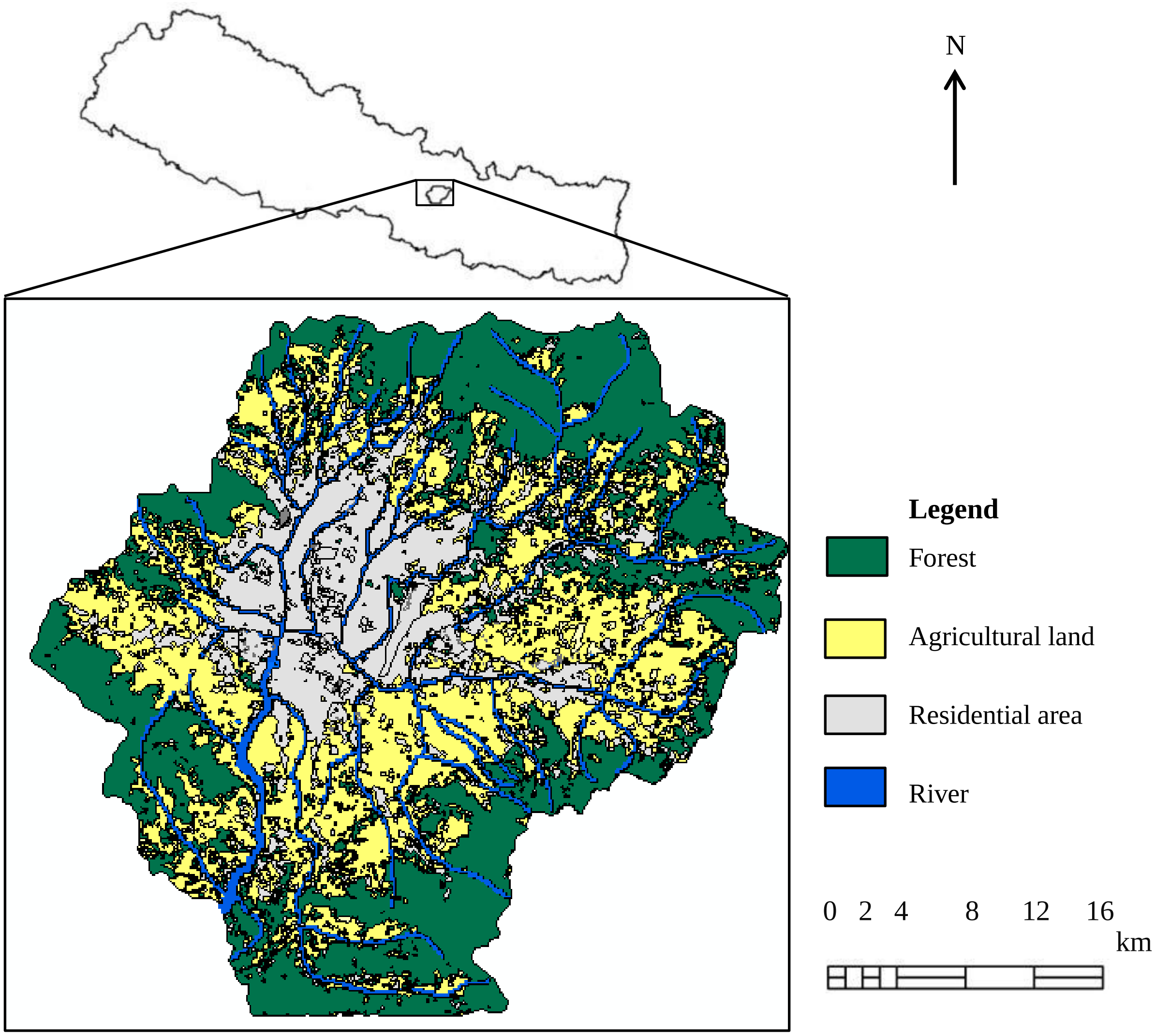


Figure 1.1 Land use map of Kathmandu valley

alternative water supply sources to meet their demands. Since those alternative supply sources vary in terms of qualities, reliability, accessibility and cost (Howard *et al*., 2002), their selection may be influenced by socio-economic characteristics of households. Moreover, monitoring and management of those sources are needed to conserve and manage them and to reduce households' health exposure to microbial health risks.

1.2 Research Objectives

In order to reduce the problem of water scarcity, there is need of water management measures. However, for undertaking any water resources management measures, full understanding of existing water supply sources, water consumption pattern and water quality of those sources are needed. Moreover, people's perception and cost of water management measures also play key role in success and adoption of those measures. Therefore, the major objective was to study water consumption pattern for water management measures at household level.

For achieving the major objective of this study, following specific objectives were established:

1. To analyze influence of socio-economic characteristics on water consumption patterns
2. To estimate water consumption for potable and non-potable purposes at household level
3. To understand microbial health risk due to consumption of contaminated water
4. To identify suitable water management measures based on water consumption patterns

For achieving the objectives of the study, the information was collected by conducting following surveys:

(i) Water consumption survey

This survey was conducted during December 2011 and January 2012 and its purposes were to collect information about general socio-economic condition of households, water supply sources and consumption and households' coping measures.

(ii) Micro-components of water consumption survey

This survey was conducted in January 2012 and its purpose was to estimate amount of water consumption for different activities.

(iii) Microbial water quality survey

This survey was conducted in February-March 2013 and its purpose was to estimate microbial contamination during piped water distribution and examine pathways of contamination at household level.

This dissertation consists of seven chapters, including conclusion and recommendation as shown in **Figure** 1.2. Based on research background, the major objective of the study was established as to recommend suitable water management measures at household level having different water consumption patterns. Firstly, water consumption survey was conducted to identify the factors influencing selection of water supply sources. Secondly, the volume of water consumed for each activity and by different water supply sources users were estimated (Chapter 4). Also the factors influencing water consumption was identified (Chapter 4). Thirdly, microbial water quality survey was conducted to determine microbial water contamination during piped water supply and at point of uses in the house (Chapter 5). The exposure of household due to consumption of contaminated water was also estimated (Chapter 5). Finally, potential of rainwater harvesting and gray water use to improve water availability at household level for non-potable purposes was examined.

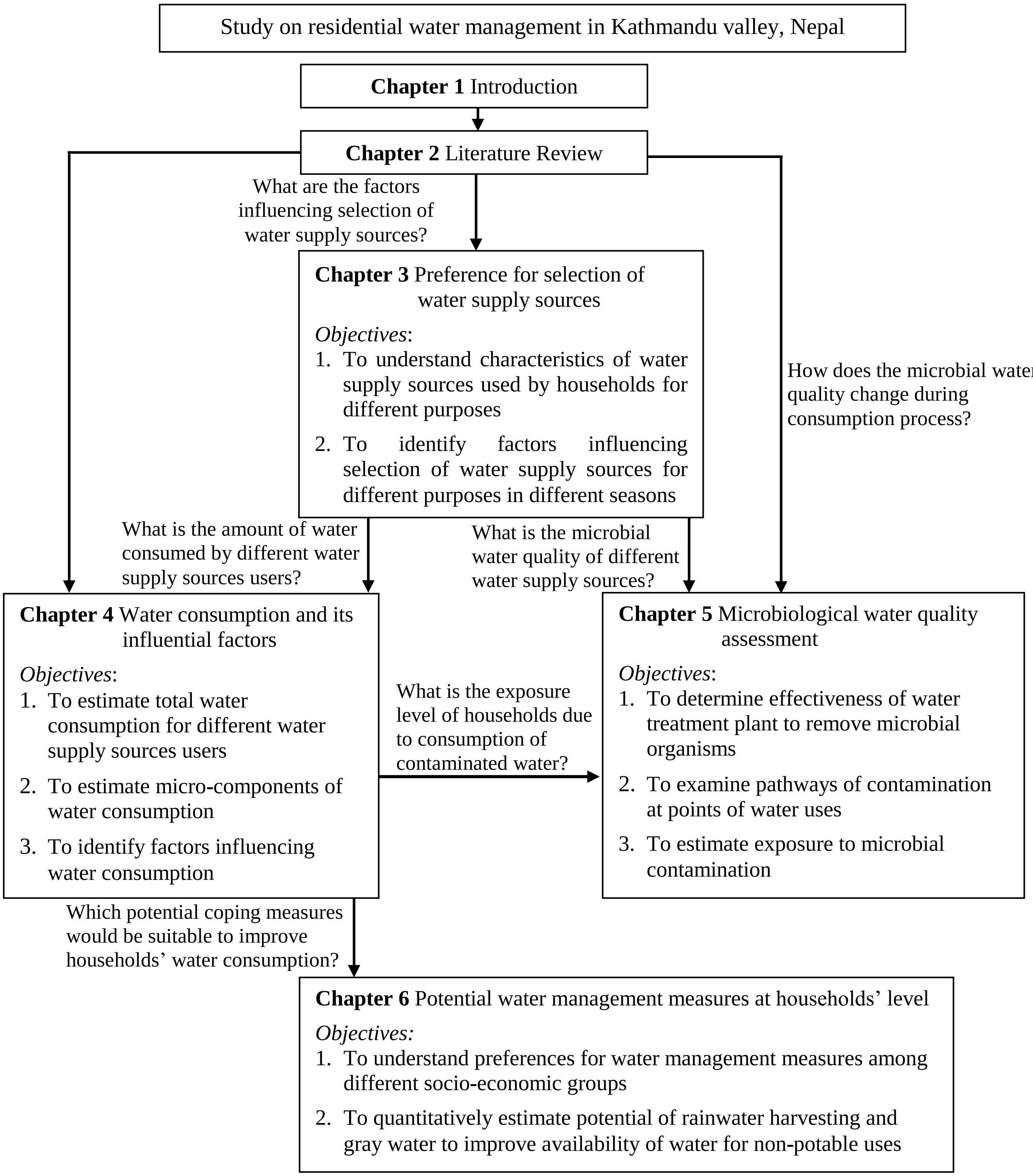


Figure 1.2 Framework of the study

Chapter 2

Literature Review

2.1. Water supply in Asian countries

Developing countries in Asia lag behind for achieving MDG water and sanitation targets – higher in rural areas and relatively lesser in urban areas (WHO and UNICEF, 2010). Globally and in Asian countries, progress on improving water supply had stalled during 2000-2008. **Table 2.1** shows proportion of urban population having access to improved drinking water in selected South Asian and South East Asian countries. South Asian countries, especially Bangladesh and Nepal, not only lag behind than other countries but their achievements have rolled back. Urban areas are developing and expanding very rapidly. According to 'the 2009 revision of World Urbanization Prospects' (UN Population Division) 390 million urban population will be added in Asia during 2005-2015. Due to unplanned urbanization, cities are facing problems in providing basic services such as housing, water, sanitation, health, education, to its growing population.

Table 2.1 Proportion of urban population with access to improved drinking water (%)

Countries	**2000**	**2008**	**2015***
Global	96	96	96
Asia	95	95	95
South Asia	93	95	97
Bangladesh	86	85	84
Nepal	94	93	92
Sri Lanka	95	98	100
South East Asia	92	92	92
Thailand	98	99	100
Vietnam	94	99	100

*Estimated based on the progress rate between 2000 and 2008

Source: WHO and UNICEF (2010)

Development of water supply infrastructure has not been proportionate in comparison with its demand or necessity. **Table 2.2** shows comparison of constraints of water supply for Kathmandu with other South Asian and South East Asian cities. The proportion of households, depending on private self-supply sources such as private wells, rainwater or private suppliers such as bottled water was reported to be higher in Kathmandu than other cities which have higher coverage of piped water supply and regular supply. Unlike other cities, Kathmandu suffers from intermittent piped water supply.

Tariff rate of piped water supply of Kathmandu was lower than Bangkok and Hue. Due to low tariff rate, the water supply utility of Kathmandu could not recover its operating cost, which has implication on provision of services by utility. High connection fee was reported as a barrier for urban poor from accessing piped water connection in Kathmandu. The households without piped water connection purchase water from water retailers at high cost. In Kathmandu, water retailers charge as high as USD 6 for 1 m^3 of water. Surface and ground water pollution were other constraints of major concern for water supply in Kathmandu and other cities.

Table 2.2 List of constraints for water supply in selected Asian cities

Cities / Constraints	Kathmandu	Bangkok	Danang	Hanoi	Hue	Kandy	Khulna
Coverage of piped supply system (%)	78	99	59	85	99	60	15
Leakage (%)	40	28	30	40	15	40	25
Intermittent supply	2 h /2d	24 h/d	NA	•	•	NA	5 h/d
Tariff rate (USD/10m^3)	0.7	3.99	0.18	0.19	1.82	0.47	0.81
Connection fee (USD)	150	116	60	60	60	NA	NA

•: Constraint exists; NA: Information not available

2.2. Description of Kathmandu valley

Kathmandu valley covers an area of 685 km^2 (NTNC, 2009) and its population is estimated to be 2.4 million in 2011 (CBS, 2012). The map of Kathmandu valley is shown in **Fig. 2.1**. Kathmandu Valley is composed of 3 districts *viz*. Kathmandu, Lalitpur, Bhaktapur. These districts constitute of 5 major cities. The capital city of Nepal lies in Kathmandu district. Other cities are Kirtipur in Kathmandu district, Patan in Lalitpur district, Bhaktapur and Madhyapur Thimi in Bhaktpur district. The topography of the valley comprises a flat land with average elevation of about 1300 mean sea level. Kathmandu valley receives an average rainfall of 1,400 mm/year. The valley lies in temperate climate zone having mean annual temperature of 18°C (NTNC, 2010). Bagmati River is the major river flowing through the valley. There are altogether 20 tributaries of the Bagmati River system within the valley as shown in **Fig. 2.2**.

Due to a decade-long armed conflict (1996-2006) in Nepal, population from different parts of Nepal migrated to Kathmandu valley for better security and economic opportunities. During 2000-2010, the population in Kathmandu valley has increased at rate of 5.6% annually. The rise in population has increased haphazard construction of buildings and

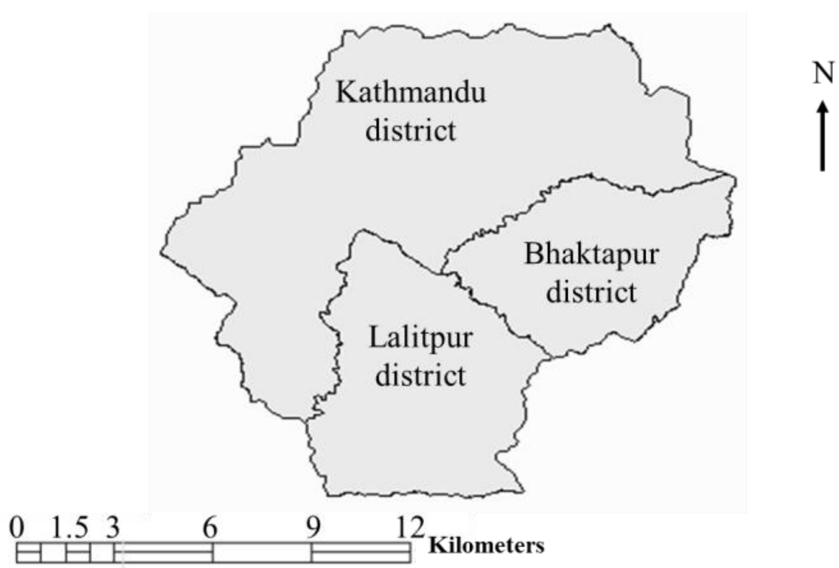


Figure 2.1 Map of Kathmandu valley

Source: NGIIP (2010)

unplanned urbanization in Kathmandu valley. The Nepal Living Standards Survey (2010-11) reported that about 50 per cent of the households in Kathmandu Valley were renters. In Kathmandu valley, a house owner/landlord rents a room or flat of a building to renters. Unlike in developed countries, house owner and renters live in the same building and renters may share piped water connection, toilet and bathroom with other households living in the building.

Due to increased population and unplanned urbanization, environmental pollution has become a major problem. Surface water pollution, improper solid waste disposal, traffic congestion and air pollution are the major environmental problems in Kathmandu valley. High demand of electricity exceeding its production has caused frequent interruption of power supply (*i.e*. load shedding) in Nepal. Load shedding has become a major hindrance for development of Nepal and for undertaking any technological solutions to resolve the environmental problems.

2.3. Water supply system of Kathmandu valley

Nepal Water Supply Corporation (NWSC) was established in 1989 for management of water supply in urban areas of Nepal. In 2006, Kathmandu Valley Supply Management Act and

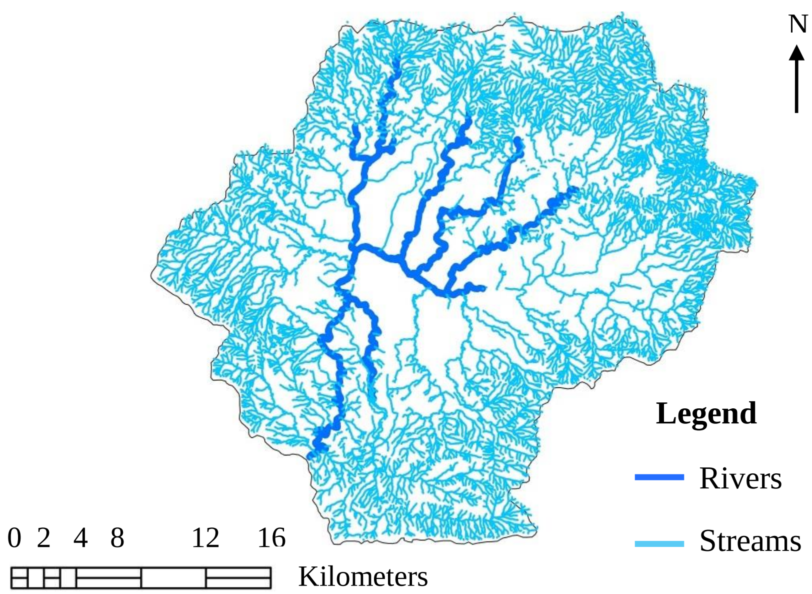


Figure 2.2 Major rivers network of Kathmandu valley
Source: NGIIP (2010)

Water Supply Tariff Fixation Commission Act were promulgated. Then, the responsibility of managing water supply services was handed over to three different organization *viz*. Kathmandu Valley Water Supply Management Board (KVWSMB), Water Tariff Fixation Commission and Kathmandu Upatyaka Khanepani Limited (KUKL). Since 2008, KUKL has been operating as a private organization and has license of its operation for 30 years.

Water in the Kathmandu Valley is derived from two sources: surface water (rivers and ponds) and groundwater. They are basically fed with rainfall. Over time, requirements for water for drinking and personal hygiene, agriculture, religious activities, industrial production, and recreational activities, such as swimming and fishing, have increased in the valley. Nevertheless, the rivers have become main repository for the valley's untreated sewage, solid waste, and industrial effluents.

Drinking water in Kathmandu valley is supplied from in-valley sources of water that include a number of small storage facilities, river sources, springs and spouts, and ground water. The details of each supply system are shown in **Table 2.3.** Currently, there are 20 water treatment plants (WTPs) in Kathmandu valley and the total treatment capacity is 117.0 m^3/day. WTPs supply water through 7 water distribution systems. Treatment varies from bleaching powder chlorination to conventional treatments like sedimentation, filtration and chlorination as shown in **Figure 2.3**. The study conducted by Kansakar (2005) showed that majority of the water treatment plants were in poor condition and poorly maintained. Moreover, data recording and keeping were not proper. The treated water quality was reported to be deteriorated in rainy season and did not meet the WHOS guideline for drinking water. Among these water treatment plants, Mahankalchaur water treatment

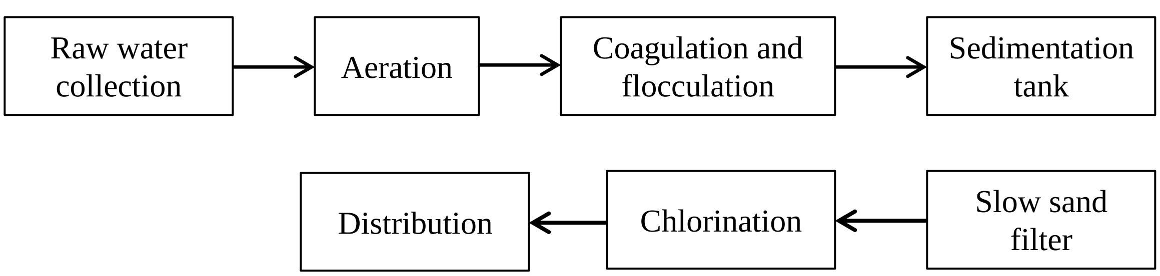


Figure 2.3 Flowchart of water treatment system of Kathmandu valley

plant was reported to work satisfactorily. **Table 2.4** shows water quality standards for drinking water recommended by government of Nepal and WHO.

Table 2.3 Water treatment plants (WTPs) of Kathmandu valley

Water treatment plant	**Sources**	**Capacity (m^3)**
Balaju	Surface and ground water	10.0
Balkhu	Surface water	3.0
Bansbari	Surface and ground water	22.0
Bode	Surface and groundwater	20.6
Mahankalchaur	Surface and ground water	26.5
Sundarijal	Surface water	21.6
Other 14 small WTPs	Surface water	13.3
Total		117.0

Source: KUKL (2008)

Table 2.4 Water quality standards for drinking water

Water quality parameters	**Nepal**	**WHO**
Turbidity (NTU)	5	5
pH	6.5-8.5	6.5-8.5
Conductivity (μS/cm)	1500	-
Iron (mg/L)	0.3	0.3
Arsenic (mg/L)	0.05	0.01
Cyanide (mg/L)	0.07	0.07
Fluoride (mg/L)		1.5
Nitrate (mg/L)	50.0	50.0
Mercury (mg/L)	0.001	0.001
E.coli (CFU/100 mL)	0	0
Total coliform (CFU/100 mL)	0	0

Source: KUKL (2008

2.4. Existing water laws relating to drinking water supply, sanitation and water pollution in Nepal

Drinking water has been recognized as the basic minimum need for all citizens of Nepal. The Government of Nepal is committed for provision of convenient, safe, and adequate drinking water. Water Resources Act 1992 has appropriately recognized drinking water as the first priority in terms of order of use, followed by irrigation, farming enterprises like animal husbandry and fisheries, hydroelectric power, cottage industry, water transport, and others. Other water related laws are shown in **Table 2.5**.

The government has undertaken following efforts to increase people's access to drinking water: (i) Rainwater harvesting programs (ii) Community based water supply and sanitation sector projects in partnership with non-governmental sectors (iii) Water quality improvement program; and (iv) Sanitation education and hygiene promotion program.

Table 2.5 Lists of relevant water laws in Nepal

Laws	**Summary**
Nepal Water Supply Corporation Act 1989	• Authorizes Nepal Water Supply Corporation for providing drinking water, sanitation and sewerage • Articulates duties and responsibilities of the corporation
Water Resource Act 1992 and Regulation 1993	• Defines order of priority of water use 1. Provides guideline for registration of water user association and articulates their rights and obligations
Environment Protection Act 1996 and Regulation 1997	2. Sets out regulations for prevention and control of pollution
Drinking Water Regulation 1998	3. Regulates use of drinking water and states drinking water quality standards

Source: Water Aid Nepal (2005)

2.5. Factors influencing selection of water sources

Insufficient and unreliable piped water supply, often forces households to look for alternative water sources to fulfill their water demands. In developing countries households have been reported to use multiple water sources (Nauges and Berg, 2009; Basani *et al*., 2010). Income, price of water, residence, education of household head and distance between the residence and water sources and time spent for collection of water have been reported to be influential on household choices of water supply sources have also been reported to influence selection of water sources (Mu *et al*., 1990; Amponsah *et al.*, 2009). Madanat and Humplick (1993) observed that different water supply sources were used for different purposes, since different source offered different qualities, reliability, and accessibility and cost. However, there is lack of study on identifying factors influencing selection of water supply sources for different purposes.

Commonly, two types of models are used for prediction of households' water supply source selection *i.e.* (i) a binary-logit model and (ii) multinomial logit (MNL) model. A binary logit model is mostly used to predict a household would connect to piped water supply, while multinomial logit is used to predict which source a household would choose, if it can choose among multiple water supply sources. The explanatory variables for these models can be classified as (i) socio-economic characteristics of households and (ii) characteristics of the water supply source which influence households' judgment.

2.6. Micro-components of water consumption

Understanding of amount of water consumption for different purposes will enable water managers to estimate quality and quantity of water demand. **Table 2.6** shows range of estimates of per capita water requirements ranging from 20 liters/capita/day (L/cap/day) to 4,654 L/cap/day. WHO and UNICEF (2000) suggested 20 L/cap/day as minimum amount of water required for domestic hygiene purposes from a source located within one kilometer of a person's residence. Gleick (1996) suggested a minimum of 50 L/cap./day as the basic water requirement for drinking (5 L/cap/day), hygiene and sanitation services (20 L/cap/day), bathing (15 L/cap/day) and food preparation (10 L/cap/day). With basic access of approximately 20 L/cap/day (7.3 m^3/cap/year) it is unlikely that all water requirements for hygiene will be met; at 50 L/cap/day (18.3 m^3/cap/year) (intermediate access) most requirements can be met, and at 100 L/cap/day (36.5 m^3/cap/year) (optimum access) all requirements can be met.

Falkenmark (1986) considers that 4,564 L/cap/day of water is needed for domestic agricultural and industrial activities and availability of water below 4,564 L/cap/day was referred as "water stressed conditions". Moreover, availability of water below 2,738 L/cap/day will begin to adversely affect human health, well-being and economic development.

2.7. Factors influencing residential water consumption

Water consumption in the urban environment tends to be dynamic. Gazzinelli *et al.*, (1998) and Keshavarzi *et al*. (2006) showed that certain socio-economic and cultural factors, house quality, type of water source and a utility index were significantly correlated with water use. Income, water prices and taxes have been widely recognized as the factors influencing water consumption and under different contexts these determinants have been found to vary as shown in **Table 2.6**. Gatersleben *et al*. (2002) found that household size influenced water consumption.

Table 2.6 Estimates for minimum water requirement

Reference	Estimate (L/cap/day)	Remarks
WHO/UNICEF (2000)	20	Basic domestic health and hygiene needs
Gleick (1996)	50	Basic domestic health and hygiene needs
Howards and Batram (2003)	100	All domestic health and hygiene needs
Falkenmark (1986)	4,564	Domestic, agricultural and industrial needs

Loh and Coghlan (2003) found that indoor water consumption was influenced by household size and water consuming appliances. Other variables considered are area of house, size of garden and irrigated land (Hewitt and Hanemann, 1995), number of bathrooms (Zhang and Brown, 2005), multiple wealth indices and home ownership (Jones and Morris, 1984).

Occupancy has also been reported to influence on per capita water consumption. Although an increase in the number of inhabitants per household increases the total domestic water consumption, per capita consumption decreases with increased occupancy (Butler, 1993; Edwards and Martin, 1995). The distance of water source from the residence has been identified as a major determinant of water consumption (Demeke, 2009). Households located nearer to the water source are likely to use water more than others located farther away. Besides socio-economic factors, previous researches have also reported that water consuming behaviors of households influence per capita water consumption of households.

Table 2.7 Factors influencing per capita water consumption (L/cap/day)

Factors	**Relationship**	**Reference**
Family size	Negative	Gatersleben *et al*. (2002)
Household income	Positive	Twort *et al.* (1993)
Number of children in household	Positive	Nauges and Thomas (2000)
Number of bathroom	Positive	Mukhopadhyay *et al*. (2001)
Garden size	Positive	Mukhopadhyay *et al*. (2001)
Frequency of bathing and laundry	Positive	Zhang and Brown (2005)
Possession of water heater	Positive	Zhang and Brown (2005)
Metering	Negative	Dalhuisen and Nijkamp (2001)
Temperature above 21°C	Positive	Maidment and Miaou (1986)

2.8. Water demand forecasting techniques

A better understanding of household water use in developing countries is necessary to manage and expand water systems more effectively. Due to increase of population and limited availability of freshwater supply, there is need for development of methods and identify factors that highly correlated with actual water demand and provide essential information for expansion of water supply (Griffin and Sickles, 2001). The forecasting of water demand is also important for designing, implementing and evaluating water policies. Spatial and temporal variability, characteristics of population and various water consuming appliances and past water consumption trends are vital information that are needed to be accounted for water demand forecasting (Memon and Butler, 2006).

Multivariate econometric approach based on socio-economic characteristics, climatic factors and public water policies and strategies has been conventionally used for water demand forecasting (Babel *et al*., 2007; Nauges and Berg, 2008). In recent years, researches do not only establish correlation between explanatory variables and water demand but also analyses their sensitivity using Artificial Neural Network models (Babel *et al*., 2010). Water demand forecasting may be broadly classified as short, medium, and long term prediction. Short term prediction has been mainly used for pumping and storage tank operations (Zhang *et al*., 2006). Medium and long- term predictions are useful for expansion of water supply system, policy formulation and development of demand management measures (Babel *et al*., 2010)

2.9. Water demand management

2.9.1. Introduction

Water demand management measures have been defined as policies, measures and initiatives which will control water demand by controlling water uses, improving efficiency, reducing loses, shifting time of use and increasing availability during events of drought (Brooks, 2006). White and Fane (2002) have categorized water demand management measures in following categories:

a) Increase system efficiency
b) Increase end use efficiency
c) Promoting distributed sources of supply
d) Substitute resource use
e) Improve the market in resource usage

In recent years, different demand management measures have been developed; however their suitability depends on types of consumers (Wegelin-Schuringa, 1999). These management measures incur cost and have been reported to outweigh water tariff of piped water services (Choe *et al.*, 1996). Costs of the measure and its acceptance by users are crucial for its successful implementation. The chances of successful implementation of demand management measures improve with public awareness and participation of people, especially in context of developing countries where public receive poor, inefficient and inequitable water service.

2.9.2. Gray water use

Gray water is defined as water generated after consumption for bathing, laundry, kitchen, cleaning and activities other than from toilet (Eriksson *et al*., 2002). Though toilet waste is not included in gray water but contains organic matter which can favor growth of enteric bacteria (Manville *et al*., 2001). **Table 2.8** shows microbial water quality of different sources of gray water.

For reducing consumption of potable water for non-potable purposes, the potential of gray water use for non-potable purposes been explored worldwide. For example, 29 to 47% of total domestic water consumption is used for toilet flushing, (Surendran and Wheatley, 1998; Lazarova, 2003).

Table 2.8 Indicators of bacteria in gray water from different sources (CFU /100 mL)

Gray water source	Total coliform	*E.coli*	Reference
Bath, hand basin	-	$2.5X10^4$	Albrechtsen (1998)
Bath	$3.1\ X10^6$ - $5.0\ X10^6$	$3.9\ X10^4 – 3.9\ X10^6$	Kotut *et al*. (2011)
Laundry	$2.5X10^3$-$3.1\ X10^5$	-	Christova *et al*., (1996)
Laundry	$1.5\ X10^6 – 6.3\ X10^6$	$2.5\ X10^4 – 6.3\ X10^6$	Kotut *et al*. (2011)
Kitchen sink	$1.2\ X10^6– 6.3\ X10^6$	$3.9\ X10^4 – 5.0\ X10^6$	Kotut *et al*. (2011)

Thus, using gray water for toilet flushing can reduce consumption of potable water of a household. Moreover, previous studies have reported that the amount of gray water produced in the home is sufficient for toilet flushing. Karpiscak *et a*l., (2001) reported that gray water use has the potential to exceed supply from rainwater tanks.

2.6.2. Rainwater harvesting

Rainwater harvesting refers to capturing, diverting and storing rainwater for a variety of purposes (Appiah, 2008). In different cities *viz*. Chennai and New Delhi, building plans need to have rainwater harvesting system for its approval by local government (UNHABITAT, 2005). Rainwater harvesting in a large scale has been reported in countries like Japan (Zaizen *et al*., 1999) and United Kingdom (Hills *et al*., 2001).

As shown in **Table 2.9**, water quality of stored rainwater has been found to be better than roof runoff water quality. Roofing material and its maintenance are influential in determining chemical and physical water quality of stored rainwater. Microbial quality of rainwater has often failed to meet WHO requirements for drinking water. Appan (1997) detected total and fecal coliform counts in stored rainwater and also stored rainwater may provide breeding ground for mosquitoes (Ryan *et al*., 2009). The underground storage of rainwater having temperature below 25°C has been suggested for minimizing risk of pathogen growth and boiling and chlorination have been recommended for treating rainwater (Fewkes, 2006).

Table 2.9 Quality of rainwater (summarized by Fewkes, 2006)

Water quality parameters	Roof runoff	Stored rainwater
pH	5.2-8.0	6.0-8.2
BOD (mg/L)	7.0-24.0	3.0
COD (mg/L)	44.0-120.0	6.0-151.0
Turbidity (NTU)	10.0-56.0	1.0-23.0
SS (mg/L)	3.0-281.0	0-19.0

2.10. Microbial water quality of drinking water

2.10.1. Role of microbial water quality on public health

Diarrhoeal diseases are a major cause of sickness and death among infants in developing countries (Feachem *et al.,* 1983). According to WHO and UNICEF (2000) about 4 billion cases of diarrhea occur every year, causing death of 2.2 million people worldwide. Improvements in water supply and sanitation facilities are believed to reduce transmission and ingestion of faecal and oral pathogens particularly the major infectious agents of diarrhea. Esrey *et al.,* (1985) analyzed 67 studies from 28 different countries and reported that the impacts of water supply and excreta disposal facilities on reduction of diarrheal diseases. Through the provision of water supply facilities in southern Thailand, Chongduvivatwong *et al.,* (1994) reported a reduction in diarrhea morbidity of 25%.

2.10.2. Interventions for improving water quality

For decades, many studies have been conducted to understand the relationship between improvements in one or more components of water quality and quantity aiming to reduce diarrheal disease morbidity. Studies have pointed out that improvement in water quality or quantity alone reduces diarrheal disease morbidity by only 15% and 20% respectively (Esrey, 1996). Microbiological qualities of transported and stored water have been found to be lower than at source, suggesting contamination at different stages of water consumption (Rufener *et al*., 2010). Therefore, point of use water quality improvement measures such as water treatment before consumption, and safe storage of water have been promoted for reducing burden of water borne diseases in different parts of the world (Clasen *et al*., 2007; Schmidt and Cairncross, 2008). WHO and UNICEF (2009) have recommended for integration of household water treatment and storage, along with hand-washing, community-wide sanitation, breast feeding and measles and rotavirus vaccines to prevent and treat diarrhea among children.

Disinfection based water treatment at household level have been reported to reduce risks of diarrheal disease by 17-85% (Howard and Pond, 2002). The proven household water treatment options widely used in developing countries are boiling, chlorination, flocculant/disinfectant powder, solar disinfection, ceramic filtration and slow sand filtration. Studies focused on users attitudes and aspirations are needed for improvement and scaling up of household water treatment and storage measures (Clasen, 2009).

The practice of open storage of drinking water, dipping of cups into vessels and contamination by hands and domestic livestock have been reported as predominant factors causing decline in water quality (Rufener *et a*l., 2010). Chidavaenzi *et al*. (1998) and Mazengia *et al*. (2002) found that covered vessels reduce fecal and total coliform counts in stored water by 50%. Tight fitting water container lids have been recommended to reduce the risk of dengue fever (Phuanukoonnon *et al*., 2005).

2.11. Non-parametric statistics

In statistics, non-parametric statistics are sets of statistics which do not assume the data or population have any distribution, unlike parametric statistics tests. Since, non-parametric tests have only fewer assumptions and they are more simple and robust than parametric tests, hence they are more widely applied used. However, non- parametric tests require a larger sample size than parametric tests to draw conclusions with the same degree of confidence. Some of the non-parametric tests, their purposes and equivalent parametric tests are shown in **Table 2.10**.

Table 2.10 Non-parametric tests used in this study

Non-parametric tests	**Purposes**	**Equivalent Parametric tests**
Kruskal-wallis one way analysis	To compare between more than two samples whether are independent or not and also tests whether samples belong to same distribution	One-way ANOVA
Mann-Whitney *U* test	To compare between more than two samples whether are independent or not	Independent t-test
McNemar's test	To examine the equality of proportion of samples with dichotomous traits and are correlated	Paired t-test
Pearson Chi-square test	To examine whether a paired observation on two variables are independent of each other and it is expressed in a contingency table	-

Chapter 3

Preference and selection of multiple water supply sources

3.1. Introduction

Households in Kathmandu valley have been using multiple water sources in order to cope with insufficient piped water supply (Whittington *et al*., 2002). The selection of water supply sources among multiple sources is often a complex process as the sources have different characteristics and different water supply sources have been reported to be allotted for different pruposes. Understanding of the process of selection of water sources for different purposes has implications on water demand modeling and forecasting (Mu *et al*., 1990; Zhang and Brown, 2005) and health risk assessments as those sources poses different risk of exposure to contaminants.

The government of Nepal aims to expand piped water supply coverage in Kathmandu valley, after completion of Melamchi water supply project. For expansion of piped water supply services and water supply planning, it is necessary to understand the characteristics of existing water supply sources, conditions and reasons that influence selection of those water supply sources for different purposes. Therefore, this chapter examines characteristics of water supply sources and factors that influence households for selection of water supply sources for different purposes.

The specific objectives of this chapter are as follows:

(a) To understand characteristics of water supply sources used by households for different purposes
(b) To identify factors influencing selection of water supply sources for different purposes in different seasons

3.2. Materials and Methods

3.2.1. Sampling sites

This study was conducted only in the piped water service area of Kathmandu valley. The map of the study area is shown in **Fig. 3.1**. The population of the service area is estimated to be 1.3 million in 2005 (NWSC, 2005). In 2008, 171,499 households were connected to public piped water supply network (KUKL, 2008).

Based on piped water supply distribution and rainfall in Kathmandu valley, a year was divided into 2 seasons viz. dry (Jan.-June) and wet (July-Dec.) as shown in **Fig. 3.2**. August is the wettest month receiving 300 mm and December and January are the driest months. In August, piped water supply utility supplies 150,000 m^3/day, while in March it supplies only 90,000 m^3/day. Due to reduced rainfall for 4 months consecutively, piped water supply gradually declines and increases only after rainfall in April.

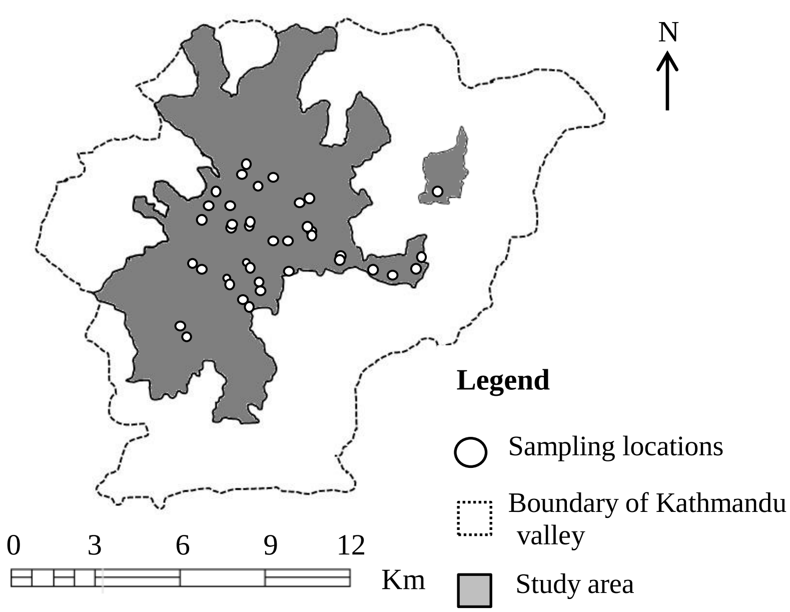


Figure 3.1 Map of study area showing sampled clusters. Cluster is an informal group of households and five households were selected from each cluster.

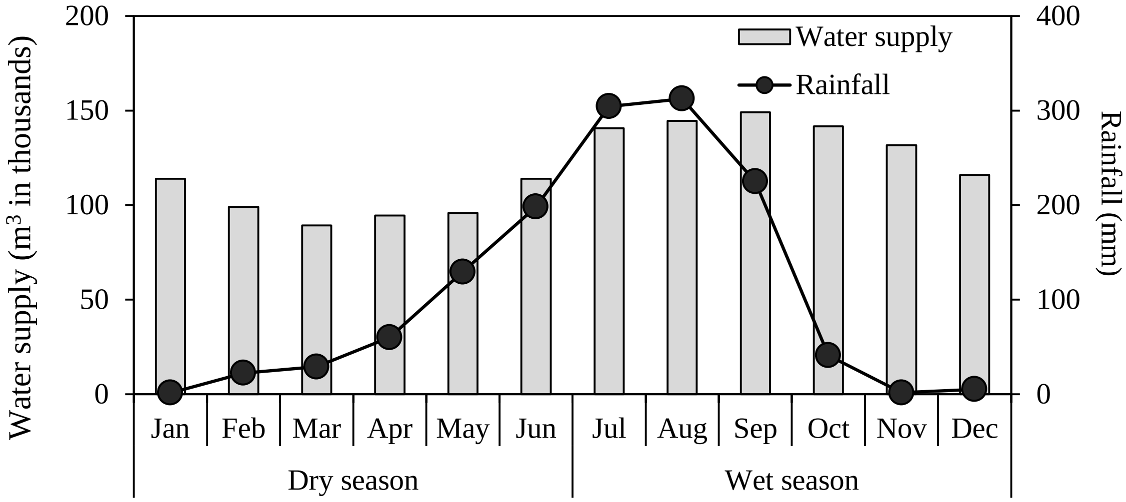


Figure 3.2 Classification of a year based on rainfall and piped water supply

3.2.2. Sample design

Multistage stratified random sampling was conducted for selection of households. Based on administrative boundary, the study area was classified into urban, peri-urban and rural zone. Sample size was determined as 0.02% of the population of each zone.

At first stage of sampling, wards (smallest administrative units) from each zone were selected. Seventeen wards of core urban area, five and one wards of peri-urban rural area were selected. Each ward consists of cluster of households. Later, two clusters were selected from each ward. Wards and cluster was listed, numerated and selected using random number table. Finally, five households were selected from each cluster. Thus, 167, 50 and 10 households were selected from urban, peri-urban and rural zone, respectively.

3.2.3. Data collection

3.2.3.1. Household interview survey

A structured household interview survey was conducted during December, 2011 and January, 2012. **Table 1** shows the contents of the questionnaire (for details please check **Appendix A**). Each households was queried about their socio-economic conditions (monthly income, family size *etc*.), water consumption pattern (water supply sources and their purposes, their perception about sources) *etc*. It took about thirty minutes to complete the interview for a household.

3.2.4. Data Analysis

Descriptive statistics like frequency, average, median and standard deviation (SD) were used to examine data on demographic characteristics, water supply sources and water consumption. The data were analyzed using PASW Statistics 18 and Microsoft Excel-2010. Since the data did not meet the assumptions of parametric tests, non-parametric tests

Table 3.1 Contents of household interview survey

Theme	Type of question	Reference
1) General information	Name of respondents Name of location	-
	Location of respondents house(using Global Positioning System)	Figure 3.1
2) Socio-economic information	Monthly income, occupation, family size Housing ownership (owner or renter) Number of house occupants Plot size area of house	Table 3.2, 3.10, 3.11, 3.12, 3.13
3) Water consumption pattern	Water supply sources and their purpose of uses	Table 3.3, 3.4
	Perception on aesthetic water quality of water supply sources	Figure3.4
	Reasons for selection of water supply sources	Table 3.9
	Duration and frequency of piped water supply	Figure 3.5
	Distance of alternative water supply sources	Table 3.15
4) Water use facilities	Capacity of storage tank Plumbing system, piped water sharing	Figure 3.6

have been used in this study. In this chapter, Mann Whitney *U* test was used to examine the socio-economic differences between house owner and renter using Eq. 3.1. Kruskal-Wallis test was used to test association between socio-economic variables and water supply sources for different purposes using Eq. 3.2. McNemar's test was used to examine change in proportion of a water supply source user during dry and wet seasons as shown in Eq. 3.3.

$$U = n_1 n_2 + \frac{n_1(n_1+1)}{2} - \sum_{i=n_1+1}^{n_2} R_i \qquad \text{Eq. 3.1}$$

Where, U = Mann Whitney U statistics

n_1 = number of observations in first sample

n_2 = number of observations in second sample

R_i= Sum of rank of i^{th} sample

$$K = (N-1)\frac{\sum_{i=1}^{g} n_i\,(\bar{r}_{i.} - \bar{r}\,)^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(r_{ij} - \bar{r}\,)^2} \qquad \text{Eq. 3.2}$$

Where, K= Kruskal-Wallis test statistics

n_i= number of samples in group i

r_{ij} = rank (among all samples) of sample j

N= total number of samples across all groups

$$\bar{r}_{i.} = \frac{\sum_{j=1}^{n_i} r_{ij}}{n_i}$$

$$\bar{r} = \frac{1}{2}\,(N+1)$$

For McNemar statistics is calculated using 2X2 contingency table.

		Dry season	
		User	Non-user
Wet season	User	a	b
	Non-user	c	d

$$\chi^2 = (b - c)^2 / (b + c) \qquad \text{Eq. 3.3}$$

Where, χ^2 = McNemar test statistics b,c = number of non-users of a water supply sources during dry and wet season, as shown in 2 X 2 contingency table

In order to understand relationship the influence of aesthetic water quality on selection of water supply sources, water quality satisfaction index (*WQSI*) was constructed. *WQSI* was based on whether a respondent was satisfied with taste, color, turbidity and color of the water supply sources and if satisfied it was coded as 1 or if unsatisfied it was coded as 0. Hence, *WQSI* is a sum of four aesthetic water quality parameters for a water supply source. undertaken by households to reduce or avoid water consumption as shown in Eq. 3.4. Theoretically, *WQSI* ranges from 0 to 4.

$$WQSI_w = \sum_{i=1}^{m} S_{iw} \ / \ n \qquad \text{Eq. 3.4}$$

Where, $WQSI_w$ = Water quality satisfaction index for a water supply source "*w*"

S_{iw} = Satisfaction on aesthetic water quality parameters "*i*" (taste, odor, color and turbidity) for a water supply source "*w*"

m = Number of aesthetic water quality parameters (4)

n = Number of users for a water supply source "*w*"

Further, chi squared test was used to examine association between use of a water supply sources for drinking purpose (if yes coded as 1, otherwise 0) with *WQSI* of the respective water supply sources.

3.3. Results and Discussion

3.3.1. General characteristics of households

In this section, descriptions of households such as respondent's gender, age, education and occupation and their family size are presented. The interview was conducted with household head (mostly men) or with his spouse. The higher proportion of respondents

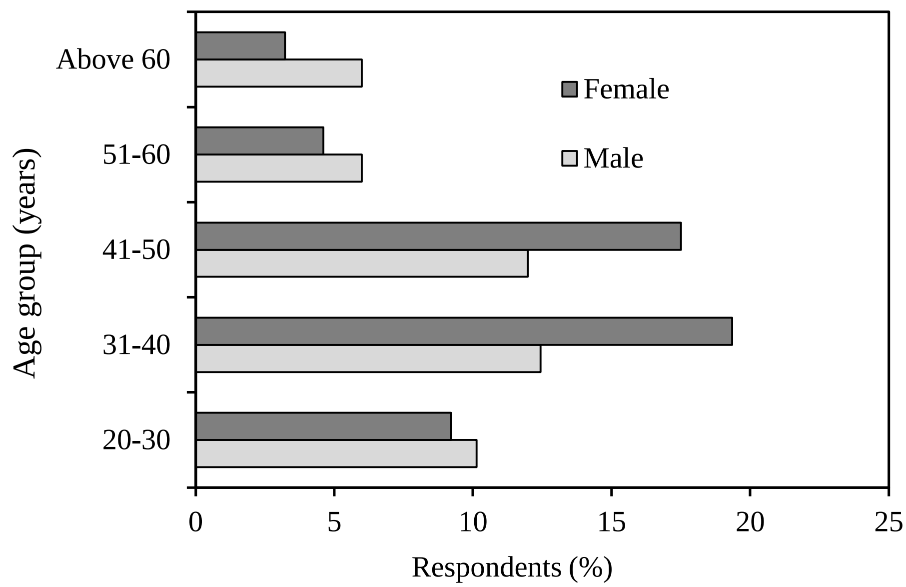


Figure 3.3 Age and gender distribution of respondents

was female (53.9%). The higher proportion of respondents (32.0%) was in age range of 31 - 40 years old, followed by 41 - 50 years old (29.4%) as shown in **Fig. 3.3**. The average ± standard deviation age of respondents was 42.0 ± 11.1 years old and none of the respondents were below age of 20 years.

Based on housing ownership, households were classified as owner (owns the land and building) and renter (temporarily rents a room or flat of the building). In context of Kathmandu valley, house owners and renter live in the same building. The house owner may or may not share toilet and bathroom with renters but latter have to share with other renters living in the same building. The higher proportion of respondents was renter (51.1%). Depending on consent of the owner, renter may use water facilities such as piped water, private well, overhead storage tanks. The buildings were not built for commercial renting purpose; therefore renters may not have access to kitchen and bathroom with a plumbing facility (*i.e.* hand basin, tap *etc.*). Only 20.7% of renter had access to kitchen and bathroom with plumbing facility, while 71.6% of owners had such facilities.

Table 3.2 General description of respondents (n=217)

Socioeconomic characteristics	Average ± standard deviation			p value
	Overall (n = 217)	Owner (n = 106)	Renter (n = 111)	
Monthly income (NRs in thousands)	21.9 ± 14.0	27.1 ± 16.4	16.5 ± 8.5	0.000
Household head education (years)	11.4 ± 4.5	10.2 ± 5.3	12.0 ± 4.2	0.004
Family size (capita/household)	4.0 ± 1.0	5.0 ± 2.0	3.0 ± 1.0	0.000
Proportion of male (%)	51.0 ± 14.5	49.5 ± 14.0	52.0 ± 15.0	0.341
[a)]Proportion of adult (%)	74.0 ± 20.1	71.6 ± 20.7	76.3 ± 20.8	0.001
[b)]Occupant (capita/house)	10.0 ± 4.0	8.0 ± 4.0	10.0 ± 4.0	0.002
[c)]Plot size area (m^2)	113.5 ± 46.1	110.7 ± 44.9	117.1 ± 43.4	0.889

Note: Statistically significant differences for socio-economic charcatersics between owner and renter was examined by Mann Whitney test
1 USD = 85 NRs (Nepalese rupees)
[a)] Adults (age group above 15 and below 60 years)
[b)] Occupant refers to total number of people living in a building
[c)] For renters, plot size of their house owners was used for the analysis.

Monthly income and family size of owners was higher than that of renters at statistical significant level (p < 0.001, Mann Whitney test) as shown in **Table 3.2**. Family size refers to the number of members having a common kitchen. Since, multiple households may be living in a house; occupants refer to total number of people living in a house. The majority of total respondents (86.6%) shared the building with other households, while only 13.3% of total respondents lived in single home. The plot size area refers to area of house building and surrounding area owned by owner of the building. In case of renter, plot size refers to that of respondent's house owner.

3.3.2. Existing water supply sources and their purposes

Households were found to use multiple water supply sources as shown in **Table 3.3**. River and groundwater were the major sources of these water supply sources. The majority of households were found to be dependent on private pipe connection and private well. Kathmandu Upatyaka Khanepani Limited, a public water supply utility was responsible for private connection and public standpipe. Tanker, vendor and bottled water were commercial water supply sources. Public well and stone spout were communal water supply sources and they were managed by the local community. Public standpipe, public well, stone spout and vendor were outdoor sources and water had to be hauled from source to residence; while, tanker and bottled water were delivered water at residence.

Table 3.3 Description of water supply sources and proportion of users (n = 217)

Water supply sources	Sources	Description	% ± S.E.
Private pipe connection	River and groundwater	Pipe connection for an individual house and only house owners pay water bills	77.4 ± 0.03
Private well	Groundwater	Well on a private land, whose use is controlled by the land owner	43.0 ± 0.04
Bottled water	River and groundwater	Commercial packaged water (20 L jar), which costs 50 NRs /jar	35.9 ± 0.04
Tanker	River and groundwater	Commercial water supplier, who supplies in bulk (5-12 m^3) and charges 240 NRs /m^3	14.3 ± 0.03
Vendor	River and groundwater	Commercial water supplier, who supplies in retail (15-25 L) and charges 300 NRs /m^3	12.9 ± 0.03
Stone spout	Groundwater	Traditional water channels carved on stones in shape of serpent head, installed on walls of sunken platform and used without any charges	10.1 ± 0.03
Public well	River and groundwater	Well on public land, which is used without any charges	8.8 ± 0.05
Public standpipe	River and groundwater	Piped connection for community and used without any charges	7.8 ± 0.03

Note: 1 USD = 84.6 NRs (as on 12 April 2013)
S.E.: Standard Error

Households were found to use different water supply sources for different purposes. As shown in **Table 3.4**, private connection, tanker, vendor and public standpipe were used for both potable and non-potable purposes. Bottled water was used for only potable purposes but private well, public well and stone spouts users used those sources mostly for non-potable purposes. Only 18.2% of households were found to consume water for outdoor activities such as watering plants or cleaning of vehicles.

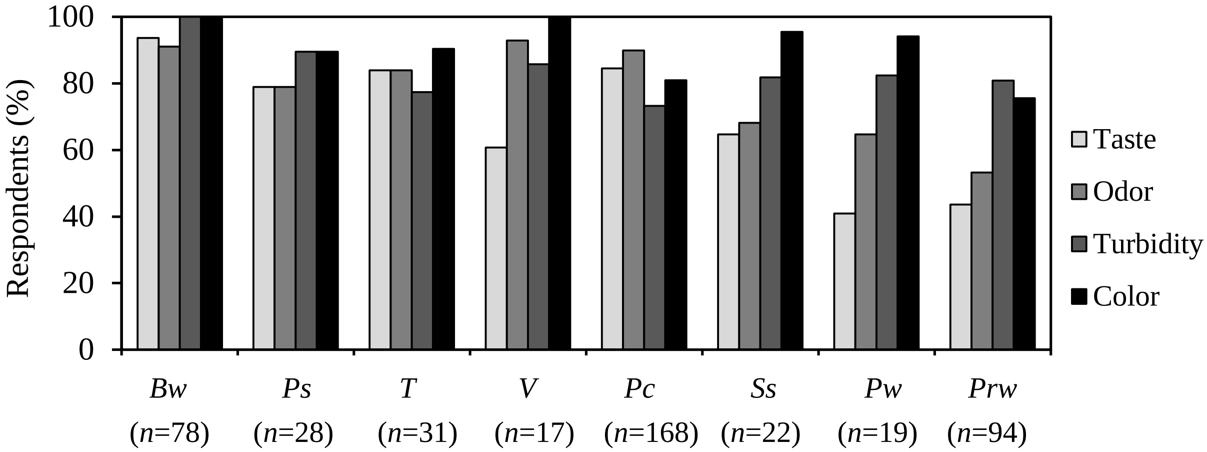
Drinking, cooking, bathing, hygiene, laundry, dishwashing, toilet and house cleaning were the major water consuming activities, while religious activities, watering plants and car and bike washing was done by 52.1%, 35.0% and 32.1% of total respondents (n = 217), respectively.

The respondents were asked whether they were satisfied with aesthetic water qualities (taste, odor, turbidity and color) of their water supply sources. **Figure 3.4** shows the

Table 3.4 Purposes of water supply sources (%)

Purposes	**Types of water supply sources**							
	Private pipe connection (n = 168)	Private well (n = 94)	Bottled water (n = 78)	Tanker (n = 31)	Vendor (n = 28)	Stone spout (n = 22)	Public standpipe (n = 19)	Public well (n = 17)
Potable use	**98.2**	**37.2**	**100.0**	**77.4**	**92.9**	**45.5**	**100.0**	**29.4**
Drinking	*86.9*	*12.8*	*100.0*	*61.3*	*57.1*	*40.9*	*100.0*	*29.4*
Cooking	*98.2*	*37.2*	*9.0*	*77.4*	*85.7*	*45.5*	*100.0*	*29.4*
Non-potable use	**92.9**	**100.0**	**0.0**	**100.0**	**92.9**	**100.0**	**100.0**	**100.0**
Bathing	*85.1*	*80.9*	*0.0*	*100.0*	*89.3*	*77.3*	*78.9*	*100.0*
Hygiene	*79.2*	*92.6*	*0.0*	*90.3*	*89.3*	*86.4*	*84.2*	*100.0*
Laundry	*78.0*	*90.4*	*0.0*	*96.8*	*89.3*	*95.5*	*57.9*	*100.0*
Dishwashing	*76.2*	*97.9*	*0.0*	*83.9*	*78.6*	*90.9*	*52.6*	*100.0*
[a]*Toilet*	*75.6*	*98.9*	*0.0*	*87.1*	*75.0*	*95.5*	*52.6*	*100.0*
House cleaning	*57.7*	*18.1*	*0.0*	*93.5*	*50.0*	*45.5*	*15.8*	*100.0*
Religious activities	*52.4*	*4.3*	*0.0*	*100.0*	*17.9*	*31.8*	*15.8*	*23.5*
Watering plants	*18.5*	*9.6*	*0.0*	*19.4*	*0.0*	*22.7*	*42.1*	*52.9*
Car/bike cleaning	*6.5*	*7.4*	*0.0*	*22.6*	*0.0*	*27.3*	*5.3*	*41.2*

Note: [a]Toilet use refer to anal cleaning and flushing
[b]Religious activities refer to water used for cleaning and offering water to deities



Note: *Bw*: Bottled water, *Ps*: Public standpipe, *T*: Tanker, *V*: Vendor, *Pc*: Private connection, *Ss*: Stone spout, *Pw*: Public well, *Prw*: Private well

Figure 3.4 Proportion of households satisfied with aesthetic water quality of sources

proportion of respondents satisfied with aesthetic quality of their sources. Water quality satisfaction index (*WQSI*) for a water supply source is the sum of the household's satisfaction on aesthetic water qualities of the source. The average water quality satisfaction index (*WQSI*) was highest for bottled water (3.9), followed by public standpipe (3.7) and tanker (3.6). The average *WQSI* of private well was lowest for private well (2.5) followed by public well (2.8). Iron concentration of wells in Kathmandu valley exceeded the Nepali drinking water standard *i.e.* 0.3 mg/L for iron content (Warner *et al.*, 2007). Water with high iron concentration has been reported to be unpalatable due to poor taste, odor and color (Emunds and Smedly, 1996).

Chi-square test was done to examine the relationship between *WQSI* and use of water supply sources for drinking purpose; however the association between *WQSI* of bottled water and public standpipe with uses of those sources for drinking purpose was not examined, since 100% of bottled water and public standpipe users used them for drinking purpose.

The association between *WQSI* and use of water supply sources for drinking purposes was found to be statistically significant. It can be inferred that users' perception on aesthetic water quality of their supply sources influenced their selection of water supply sources for drinking purpose. Madanat and Humplick (1993) also had found that perception on water quality was major determinant for selection of water supply sources for drinking purpose in slums of Faisalabad.

The respondents were also asked for reasons not using water supply sources for drinking purposes other than dissatisfaction with aesthetic water quality of supply sources, which is summarized in **Table 3.5**. Those reasons included prior experience of diseases, lack of trust on supplier or they feel it's not safe, advised as unsafe source by neighbors or local organizations, unhygienic management of sources such as open wells and dirty buckets and rope lowered into wells and also media report on water supply sources. Households had also tested quality their water supply sources and advised as unsafe to use for drinking purpose. From **Table 3.5** it is evident that awareness raising on water quality of supply sources can modify people's water use habits.

Stone spout and public well are communal water supply sources and they shared similar characteristics; henceforth they are together referred as community water supply sources.

Table 3.5 Reasons for not using water supply sources for drinking purpose (%)

Water supply source users	Prior experience of diseases	Distrust supplier	Advised as unsafe	Poor management of sources	Media (newspaper, radio *etc.*)	Do not know
Private well (*n* = 82)	8.5	12.3	19.5	18.2	-	7.3
Private connection (*n* = 23)	4.7	11.9	-	-	6.5	-
Stone spouts (*n* = 13)	15.3	-	-	-	-	58.3
Tanker (*n* = 12)	33.3	75.0	0.0	-	-	-
Vendor (*n* = 12)	16.7	25.0	0.0	-	-	58.3
Public well (*n* = 12)	16.6	0.0	41.8	25.0	-	16.6

3.3.3. Seasonal uses of water supply sources

The respondents were asked for information on uses of water supply sources during different months for different purposes. Based on piped water supply and monthly rainfall, months were grouped as dry (Jan. - June) and wet (July – Dec.) season

Households were found to use different water supply sources in different season. The proportion of water supply sources users using the water supply sources for potable and non-potable uses in dry and wet season was shown in **Table 3.6**. Decline of proportion of households using private pipe connection and private well for potable and non-potable use was statistically significant ($p < 0.001$) during dry season, while increases of proportion of tanker, Due to drying of water sources, total capacity of the piped water supply utility to supply water reduces by approx. 26.0% in the dry season than in wet season (KUKL, 2008). Private well users (n = 98, 47.8%) reported that the water level of their wells declined during dry season. Therefore, the number of tanker, vendor and bottled water users were found to increase during dry season. The number of public standpipe users in the dry and wet

Table 3.6 Proportion of water supply sources users for potable and non-potable use during dry and wet seasons (n = 217)

Water supply source users	Potable			Non-potable		
	Wet season	Dry season	*p* value	Wet season	Dry season	*p* value
Private pipe connection	52.5	36.4	0.000	31.8	21.7	0.000
Private well	6.5	1.8	0.002	43.3	35.9	0.000
Community sources	6.0	7.4	1.000	12.4	12.9	1.000
Tanker	0.9	4.1	0.016	5.1	13.8	0.000
Vendor	0	5.5	0.000	1.8	10.1	0.000
Public standpipe	7.4	7.4	-	5.5	5.5	-
Bottled water	26.7	37.3	0.000	0	0	-

Note: Statistically significant differences for water sources selection in different seasons was examined by McNemar’s tests seasons was found to be unchanged for both purposes. As discussed earlier, households used different sources for potable and non-potable uses; hence combined multiple sources to meet their needs. The combination of water supply sources varied during dry and wet season, as shown in **Table 3.7**. It was found that only 44.5% of respondents (*n* = 217) did not change their water supply sources during different seasons. Similar as in **Table 3.6**, only private connection users declined in dry and increased during wet season, while those combining bottled water or tanker or vendor with private connection increased in dry than in wet season.

Table 3.7 Existing combinations of water supply sources in different seasons (*n* = 217)

	Sources combination	Dry season (%)	Wet season (%)	Unchanged (%)
1.	*Pc*	12.9	23.0	8.2
2.	*Pc + Prw*	12.4	19.8	8.2
3.	*Pc + Prw + Bw*	11.1	11.1	7.9
4.	*Pc + Bw*	10.1	10.1	3.5
5.	*Pc + T*	6.0	1.8	1.8
6.	*Pc + Cs*	5.1	7.4	4.1
7.	*Prw+ Bw*	4.6	6.0	0.0
8.	*T + Bw*	4.6	1.4	0.0
9.	*Ps*	3.7	5.1	2.8
10.	*V*	3.2	0.0	0.0
11.	*Pc+ V*	2.8	1.8	0.5
12.	*Cs*	2.8	3.7	1.9
13.	*T*	2.8	0.0	0.0
14.	*Prw + Cs*	2.3	0.0	0.0
15.	*Prw + V*	2.3	0.5	0.0
16.	*Prw*	1.8	4.1	1.3
17.	*Bw + Cs*	1.8	0.5	0.5
18.	*CS + Ps*	1.8	0.9	0.9
19.	*Bw + V*	1.8	0.0	0.0
20.	*Pc+ Bs + V*	1.4	0.0	0.0
21.	*Ps + Prw*	1.4	1.4	1.4
22.	*Cs + V*	0.9	0.0	0.0
23.	*Pc + BW + T*	0.5	0.5	0.5
24.	*Pc + P*s	0.5	0.5	0.5
25.	*V + Ps*	0.5	0.0	0.0
26.	*Prw + T*	0.5	0.5	0.5
27.	*Pc + Bw + Cs*	0.5	0.0	0.0
	Total	100.0	100.0	44.5

Note: *Pc* (Private pipe connection), *Prw* (Private well), *Bw* (Bottled water), *Cs* (Community sources), *T* (Tanker), *V* (Vendor), *Ps* (Public standpipe)

3.3.4. Preferences of water supply sources

Respondents were asked for reasons for selecting and using the water supply sources, which are summarized in **Table 3.8**. The majority of respondents responded that they used the alternative water supply sources to supplement insufficient piped water supply. The water supply utility supplied water to different section of service area in rotation basis, ranging from two hours in a day to two hours in seven days. **Figure 3.5** shows proportion of the alternative water supply sources users in different piped water supply zones receiving piped water for varying frequency and duration. The proportion of alternative water supply sources users such as private well or bottled water users were fewer in areas receiving piped water supply more frequently. The majority of alternative water supply sources users received piped water supply only for 2h/5 to 2h/7 days. Household, who were not connected to piped water supply, also fulfilled their water demands from alternative water supply sources. Moreover, households located closer to the sources received piped water supply more frequently than those farther away.

Private well, tanker and bottled water users reported that those sources were convenient to access. Private well could be easily accessed at any time of a day without queuing. Tanker and bottled water suppliers delivered water at house, unlike vendor and community sources which had to be hauled from the source to residence.

Table 3.8 Multiple reasons for selection of water supply sources (%)

Reasons	Private pipe connection (n = 168)	Private well (n = 94)	Bottled water (n = 78)	Community sources (n = 35)	Tanker (n = 31)	Vendor (n = 28)	Public standpipe (n = 17)
Insufficient piped water supply	-	90.3	48.6	87.4	96.9	100.0	-
Cheap	79.9	100.0	42.8	84.4	90.3	50.0	47.4
Easy to access	94.6	74.2	100.0	0	0	28.6	100.0
Good quality	65.4	28.0	100.0	48.6	15.6	17.9	100.0

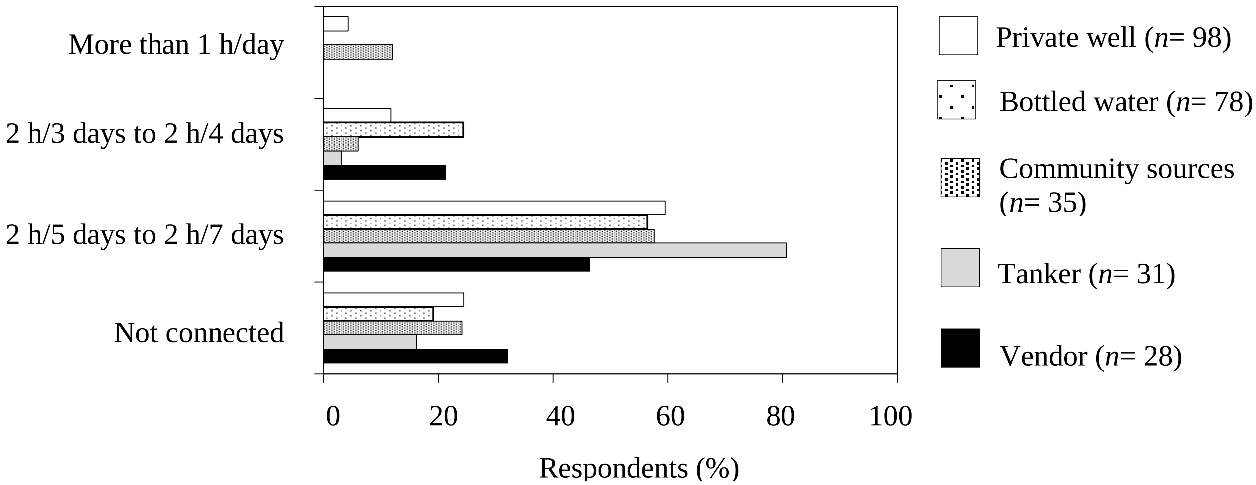


Figure 3.5 Proportion of water supply source users in different piped water supply zones

Only house owners paid water tariff for private pipe connection and renters did not have to incur any expenses for private pipe connection. Public standpipe and community supply sources were free water supply sources. Though, private well water was for free but house owners incurred electric cost for pumping water or bucket and rope for manual withdrawal of water, including construction and maintenance costs. Bottled water and public standpipe users believed those water supply sources as good water quality supply sources, which is also supported by **Fig. 3.4**.

3.3.5. Determinants for selection of water supply sources

The socio-economic factors that influenced selection of water supply sources for potable and non-potable purposes in different seasons were analyzed. **Table 3.9** and **3.10** show factors influencing selection of water supply sources for potable purposes during wet and dry seasons. Monthly income and education of households was found to be significantly ($p < 0.001$) different across water supply sources users during both seasons.

The median monthly income of private well users was the lowest, while bottled water user had the highest monthly income than other supply sources users during wet season as

Table 3.9 Association between socio-economic characteristics and water supply sources for drinking during wet season (median value)

Socio-economic variables	Private pipe connection (*n* = 116)	Bottled water (*n* = 58)	Private well (*n* = 14)	Community sources (*n* = 13)	Public standpipe (*n* = 16)	*p* value
Monthly income (NRs in thousands)	15.0	26.0	13.5	15.0	10.0	0.000
Education (years)	12.0	15.0	12.0	8.0	9.0	0.000
Number of occupant (capita)	9.0	8.0	12.0	9.0	9.0	0.182

Note: Statistically significant differences were examined among different supply sources users by Kruskal Wallis test

shown in **Table 3.9**. Households' education for bottled water users was higher than other supply sources users. Since bottled water was expected to be better quality, it can be inferred that bottled water users were aware about health benefits of bottled water. In contrast, low educated households were found to use community sources for potable use. High amount of nitrate and microbial contamination have been reported in stone spouts (Warner *et al.*, 2007). The consumption of poor quality water for potable use can be inferred as lack of awareness about water quality among community sources users. The number of occupants (total number of people living in the building) was not statistically different for selection of sources for drinking purpose during wet season. The possible reason for it could be sufficient piped water supply during the wet season.

From **Table 3.10** it can be inferred that low income households used community sources, while high income households used tanker for non-potable purposes during dry season. Similar to wet season, household heads of those using community sources were least educated than other water supply sources users. The number of occupants was the least for households using private connection for drinking purpose, while the highest for vendor users.

Table 3.10 Association between socio-economic characteristics and water supply sources for drinking during dry season (median value)

Socio-economic variables	Private pipe connection (n = 79)	Bottled water (n = 78)	Private well (n = 4)	Tanker (n = 9)	Community sources (n = 16)	Vendor (n = 12)	Public standpipe (n = 16)	p value
Monthly income (NRs in thousands)	15.0	23.0	24.0	38.0	10.0	13.5	10.0	0.000
Education (years)	12.0	12.0	12.0	15.0	7.0	15.0	9.0	0.000
Number of occupant (capita)	7.0	9.0	11.0	12.0	12.0	14.0	9.0	0.002

Note: Statistically significant differences were examined among different supply sources users by Kruskal Wallis test

Unlike in wet season, monthly income of private well users was higher than other supply sources users. During dry season, low income private well users shifted to other supply sources for potable use, while high income private well users did not shift to other supply sources, because high income private well users used deep wells (> 50 m), while low income private well users used shallow deep wells (< 50 m). The water level of deep wells did not fluctuate as in shallow wells during dry season.

The number of occupants for private connection users was lower during dry season than wet season. According to the rules of piped water supply utility, only single piped water connection was allowed per building. Since, piped water supply declined during dry season, households with higher number of occupants shifted to other supply sources, because it was insufficient for all households in the building, who share the piped water connection.

Table 3.11 and **3.12** show factors influencing selection of water supply sources for non-potable purposes during wet and dry seasons, respectively. Monthly income, plot size, education of household heads and number of occupants of various water supply sources users was statistically different at significant level ($p < 0.001$) in both seasons.

Table 3.11 Association between socio-economic characteristics and water supply sources for non-potable purpose during wet season (median value)

Socio-economic Variables	Private pipe connection (n = 69)	Private well (n = 94)	Community sources (n= 27)	Tanker (n = 11)	Vendor (n = 4)	Public standpipe (n = 12)	p value
Monthly income (NRs in thousands)	16.0	22.0	15.0	50.0	15.0	12.0	0.000
Plot size (m^2)	79.4	127.1	86.8	127.1	74.2	63..5	0.000
Education (years)	12.0	14.0	8.0	15.0	12.0	9.0	0.000
Number of occupant (persons)	8.0	11.0	8.0	12.0	16.0	8.0	0.000

Note: Statistically significant differences were examined among different supply sources users by Kruskal Wallis test

Table 3.12 Association between socio-economic characteristics and water supply sources for non-potable purpose during dry season (median value)

Socio-economic variables	Private pipe connection (n = 47)	Private well (n = 78)	Community sources (n = 28)	Tanker (n = 30)	Vendor (n = 22)	Public standpipe (n = 12)	p value
Monthly income (NRs in thousands)	14.0	20.0	13.5	35.5	13.5	12.0	0.000
Plot size (m^2)	79.8	127.1	79.8	143.7	95.5	63.5	0.000
Education of household head (years)	12.0	14.0	8.0	14.0	13.0	9.0	0.025
Number of occupant (persons)	7.0	10.0	9.0	12.0	13.0	8.0	0.000

Note: Statistically significant differences were examined among different supply sources users by Kruskal Wallis test

Monthly income of households using tanker was the highest, while public standpipe users had the lowest monthly income than other water supply sources users during wet and dry seasons. Tanker cost NRs 240/m^3 but community sources and public standpipe were used for free. Hence, costs of tanker could have been a constraint for low income households. Also, large sized storage tank was needed to store large volume of water (5-12 m^3) supplied by tanker. Since, size of storage tank positively correlated with monthly income of households as shown in **Figure 3.6**, households with higher income had tendency to purchase water from tanker, while households with low income had tendency to either purchase water from vendor in retail (15-20 L) or fetch water from community sources.

Moreover, public standpipes were common only in rural areas. Since, households in rural areas had lower income than in peri-urban and urban areas; it could be a possible reason for the lowest monthly income of public standpipe users. Though community sources were for free but they were labor intensive and time consuming (Moench and Janakarajan, 2006).

Plot size area of private well and tanker users was higher than other water supply sources users during both seasons. Due to lack of space, construction of wells and large sized storage tank for storing water supplied by tanker was not feasible for buildings built on small plot area.

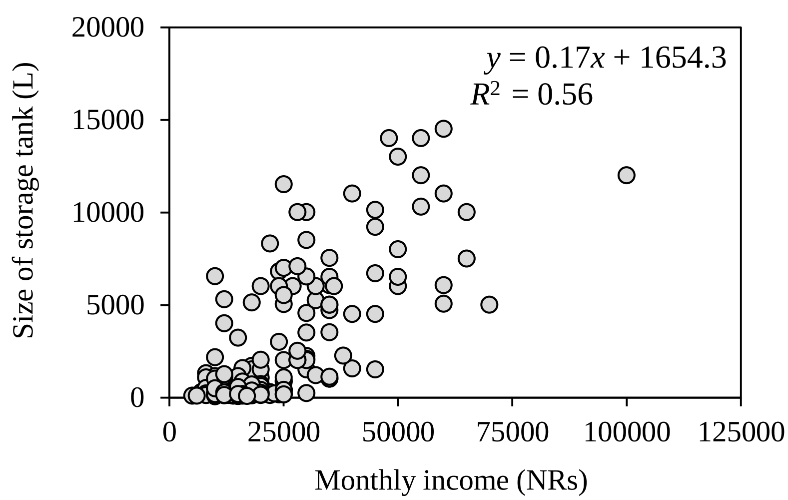


Figure 3.6 Relationship between monthly income and size of water storage tank

Education of households' head of community sources users was the lowest during both seasons. The number of occupants for vendor users was higher than other supply sources in both seasons, while it was the smallest for private connection during wet season. As discussed earlier, due to sharing of single piped connection and decline in piped water supply, fulfillment of water needs from private piped connection was possible only for households with small number of occupants.

All the water supply sources were not available to all the households. **Table 3.13** shows six conditions based on availability of water supply sources in sampled locations. Private connection, private well and bottled water were available at all sampled clusters, while community sources, vendor and public standpipe were not available at all sampled clusters, therefore, they were regarded as specific water supply sources. Distance of the sources from residence could also have influenced selection of water supply sources. Therefore, for examining influence of distance on selection of condition-specific water supply sources, households having access to the same condition-specific water supply sources source were grouped.

Table 3.14 shows median distance of users and non-users of condition specific sources *i.e.* community sources, vendor and public standpipe during dry and wet season. Only households at closer distance from community sources and vendor were found to use

Table 3.13 Available water supply sources conditions (n = 217)

Conditions	Types of water supply sources							
	Private connection	Private well	Bottled water	Community source	Tanker	Vendor	Ps	Respondents (%)
A	Y	Y	Y	N	Y	N	N	46.1
B	Y	Y	Y	N	Y	Y	N	20.7
C	Y	Y	Y	Y	Y	N	N	16.1
D	Y	Y	Y	N	Y	N	Y	8.7
E	Y	Y	Y	Y	Y	N	Y	5.1
F	Y	Y	Y	Y	Y	Y	N	2.8

Note: *Y* denotes Yes and *N* denotes No
Ps: Public standpipe

Table 3.14 Median distance of condition-specific source from residence (m)

Respondents	Potable purpose				Non-potable purpose					
	Community sources		Public standpipe		Community sources		Vendor		Public standpipe	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Users	225.0	225.0	110.0	105.0	175	200.0	72.5	110.0	130.0	130.0
Non-users	265.0	290.0	183.0	195.0	350	300.0	120.0	120.0	135.0	135.0
p value	0.680	0.578	0.403	0.640	0.001	0.067	0.045	0.230	0.423	0.423

vendor for non-potable purposes during wet season, while no effect during dry season. Hence, households at father distant fetched water from community sources and vendor during dry season. It may be due to insufficient piped water supply and drying of nearby water supply sources. Nauges and Berg (2009) have also reported influence of distance on selection of outdoor water supply sources during different seasons. Distance of public standpipe from residence of their users had no influence on selection of the source for both purposes during both seasons.

3.4. Summary

In this chapter, the existing water supply sources and socio-economic factors influencing selection of those sources were described. The majority of households were found to be dependent on multiple sources, since, piped water supply was not adequate to fulfill their needs. Well, tankers, vendors and bottled water were major alternative sources, which reduced severity of water shortage. The selection of water sources was found to be complex, since accessibility, price, quality and reliability of these sources varied. Different sources were used for different purposes and respondents' perception on aesthetic water quality of the sources influenced their selection of those sources for drinking purpose.

Due to intermittent piped water supply and poor water quality, significant number of households was dependent on multiple water supply sources. The number of private pipe connection and private well users declined during dry season, due to decrease of piped water supply and drying of wells. In contrast, number of tanker, vendor and bottled water increased during dry season.

The socio-economic characteristics of respondents were found to influence selection of water supply sources. Households' monthly income and education of household head was found to be the major influential factors for selection of water supply sources for both potable and non-potable uses during both seasons. In addition, plot size area of respondents also influenced the selection of water supply sources for non-potable uses during both seasons. Respondents having larger plot size had higher probability of constructing a private well. The size of water storage tank was positively correlated with monthly income of households and was influential for selection of tanker. Distance of outdoor water supply sources was found to be influential for selection of community sources and vendor during wet season.

Chapter 4

Water consumption and its influential factors

4.1. Introduction

In the previous chapter, the factors influencing selection of water supply sources for different purposes in different seasons were discussed. The characteristics of water supply sources were different, water consumption pattern of different water supply sources may vary. Historically, data of developed countries shows that as economy grows, water consumption increases and later becoming flat or decrease (Bengtsson, 2005). Based on trend in developed countries, lifestyle change will affect water consumption to a large extent. In context of Kathmandu valley, with improvement of piped water supply services and economic development, water consumption pattern can be expected to change. Hence it is essential to know existing water consumption patterns and factors influencing it for future demand forecasts. Moreover, change in lifestyle may not equally affect all water consuming activities, estimates of the total water consumption per capita is not enough for water supply and demand management. Thus, it is essential to understand micro-components of water consumption. Also, for calculating risk of exposure to chemical and microbial contaminants, information on volume of water consumed per capita per day is needed. Therefore, the specific objectives of this chapter are as follows:

(a) To estimate total water consumption for households using different water supply sources
(b) To estimate micro-component of water consumption for households using different water supply sources
(c) To identify factors influencing households' water consumption

4.2. Materials and Method

4.2.1. Household interview survey

As described earlier in 3.3.1, multistage stratified random sampling was conducted for selection of 217 households. A structured questionnaire survey was conducted during December, 2011 and January, 2012. In this chapter, water consumption of households was estimated using 2 methods *viz.* questionnaire survey for estimation of total amount of water and diary method for estimation of micro-components of water consumption. The estimation of total water consumption was based on respondents' responses on water bills, amount of water fetched and purchased, size of water storage tank *etc.* as shown in **Table 4.1** (see **Appendix I** for detailed information).

As discussed in chapter 3, households used different water supply sources for different purposes. Hence, depending on their water supply sources suitable Eq. 4.1, 4.2 and 4.3 were used and later added for calculation of total water consumption. Due to lack of information on water bills or size of water storage tank or amount of water fetched and purchased *etc.* total water consumption of only 147 households were estimated. Further, depending on

Table 4.1 Contents of the household interview survey

Theme	Type of question	Reference
(1) Socio-economic information	Monthly income, family size, number of occupants, housing ownership	Table 4.3, 4.4, 4.5, 4.6
(2) Water consumption	Water bills Amount of water fetched or purchase Time interval of refilling of storage containers or water purchase	Figure 4.1, 4.2, 4.3, 4.4
(3) Water use behavior	Frequency of laundry and bath	Figure 4.6, 4.7, 4.8
	Water conservation measures	Figure 4.7

purpose of the sources, the amount of water consumed for potable and non-potable purposes was estimated.

If water bills of piped water connection,

$Wcpw = (R * 1000) / N$ Eq. 4.1

Where, $Wcpw$ = Per capita water consumption for piped water (L/cap/day)

R = Meter reading for previous month (per unit equivalent to 1000 L)

N = Number of persons living in the house (capita)

If purchased from sources,

$Wcp = (Fp * Qp) / n$ Eq.4. 2

Where, Wcp = Per capita water consumption for purchases sources (*e.g.* vendor, tanker, bottled water) (L/cap/day)

Fp = Frequency of water purchase in a day (times/day)

Qp = Quantity of water purchased per times (L/time)

n = Number of household members (capita)

If fetched from sources,

$Wcf = (Fc * Qf) / n$ Eq. 4.3

Where, Wcf = Per capita water consumption for fetched sources (*e.g.* Private well, community sources, public standpipe) (L/cap/day)

Fc = Frequency of water collection in a day (times/day)

Qf = Quantity of water fetched per time (L/time)

n = Number of household members (cap/household)

$Twc = Wcpw + Wcp + Wcf$ Eq. 4.4

Where, Twc = Total water consumption (L/cap/day)

4.2.2. Measurement of micro-components of water consumption

Micro-components of total water consumption refer to consumption of water for individual purposes within a house. Different method of collection of water consumption data have been used and among those methods diary method have been reported to be more accurate (Levallois *et al*., 1998). In order to measure volume of water consumption for different activities (*i.e*. drinking, cooking, hygiene, bathing, laundry, dishwashing, toilet, housing cleaning, religious activities, gardening and car and bike washing), the diary method was used. Among 217 households, 32 households were selected for this purpose.

As described before, the majority of households in Kathmandu valley did not have access to kitchen and bathroom with plumbing facility. Therefore, for direct measurement of water consumption for each activity, the size of buckets and other utensils used by households for water consumption for the activity was measured. Then, households were asked to record number of times they use the bucket or other utensils for a particular activity for seven consecutive days. Hygiene refers to body washing, tooth brushing and mouth rinsing. For measuring volume of water consumed for bathing using shower heads or tap, household members were requested to bath on a tub and water collected in the tub was measured. Laundry was done manually in all sampled households. Based on diary method, total water consumption (L/cap/day) of households was calculated as shown in Eq. 4.5.

$$Twc = (D + C + H + B + L + U + T) / (n * 7) \qquad \text{Eq. 4.5}$$

Where, T*wc*: Total water consumption (L/cap/day)

D: Water consumption for drinking (L/household/week)

C: Water consumption for cooking (L/household/week)

H: Water consumption for personal hygiene (L/household/week)

B: Water consumption for bathing (L/household/week)

L: Water consumption for laundry (L/household/week)

U: Water consumption for dishwashing (L/household/week)

T: Water consumption for toilet (L/household/week)

n: Household size (cap/household)

4.2.3. Data Analysis

Descriptive statistics like frequency, mean and median were used to examine data on demographic characteristics, water supply sources and water consumption. A stepwise multiple linear regression analysis was done to understand relationships between dependent variable (daily total water consumption per person) and independent variables (monthly income, household size, number of faucets *etc.*). The conceptual model for water consumption is as follows:

$$Y = a + \sum_{i=1}^{n} b_n X_n \qquad \text{Eq. 4.6}$$

Where Y= dependent variable (total water consumption),

a= intercept (constant)

X_n = independent variables (socio-economic variables)

b_n= coefficient of independent variables (X)

n= number of independent variables

For complying with normal distribution, outliers in independent variables were identified and removed. The dependent and independent variables were also transformed using natural logarithmic transformation. Though removal of outliers and transformation reduced skewness for family size and number of occupants but were not normal. Shapiro Whilk test was used to test normal distribution of the variables. For avoiding multi-collinearity, correlation analysis was done between independent variables. In case of high correlation between two independent variables, only the variable having high correlation with dependent variable was selected. Housing ownership and possession of water heater were the dummy variable and owner and possession of water heater (1) was reference.

For understanding influence of water conservation behavior of households on their water consumption, a consumer behavior index (*CI*) was constructed. The conservation measures were determined as reduction of frequency of bathing and laundry, use of gray water for gardening, flushing toilet and laundry and installation of water efficient retrofits. If a household had adopted any water conservation measures, then it was coded as 1, otherwise it was coded as 0. Then, *CI* is the sum of number of activities undertaken by households to reduce or avoid water consumption as shown in Eq. 4.7. Theoretically, the value of *CI* ranges from 0 to 6.

$$CI = \sum_{i=1}^{n} WC_n \qquad \text{Eq. 4.7}$$

Where *CI* = Consumer behavior index

WC_i = Water conservation measures (*i.e.* reduce frequency of bathing and laundry, use of gray water for gardening, flushing toilet and laundry, installation of water efficient retrofits)

n = Number of conservation measures (*i.e.* 6)

4.3. Results and Discussions

4.3.1. Amount of total water consumption

Total water consumption of households was estimated based on questionnaire survey and using Eq. 4.4. The average ± standard deviation amount of total water consumption for the study area was 32.3 ± 13.1 L/cap/day. Other studies had reported the total water consumption of households in Kathmandu valley as 73.0 L/cap/day (CIUD, 2003), 35.0 L/cap/day (CBS, 2005) and 36.5 L/cap/day (Yoden, 2012). The water consumption in core urban (37.1 ± 12.4 L/cap/day) and peri urban area (37.8 ± 11.6 L/cap/day) was found to be higher than in rural area (31.3 ± 7.3 L/cap/day). CBS (2005) also had reported higher water consumption in urban area (39.0 L/cap/day) than compared to rural area (27.0 L/cap/day).

The water consumption of households in Kathmandu valley was comparatively lower than in other South Asian cities such as New Delhi (78.0 L/cap/day), Mumbai (90.4 L/cap/day) and Kolkata (115.6 L/cap/day) (Shaban, 2008) and South East Asian cities such as Bangkok (217.0 L/cap/day) and Chiang Mai (77.0 L/cap/day) (Otaki, *et al*., 2008).

Total water consumption of higher proportion of households (51.0%, n = 147) was found to be below 35.0 L/cap/day, while only 11.9% of households had water consumption above 50.0 L/cap/day as shown in **Fig. 4.1**. The per capita water consumption was found to be log-normally distributed, verified by the Shapiro-Wilk test ($p > 0.05$) having $R^2 = 0.98$. Water consumption has been considered as an indicator of sanitary level and higher level of water consumption shows better hygienic conditions (Nnaji *et al*., 2013). Water consumption of households in Kathmandu valley was below minimum recommended value of 50.0 L/cap/day (Gleick, 1996). Thus, efforts are needed to improve water availability and sanitary conditions of households in Kathmandu valley.

In chapter 3, it was found that households used multiple water supply sources and those sources varied in terms of accessibility and affordability. Since those characteristics could influence the amount of water consumption, in following section the amount of water consumption for different water supply sources users has been discussed.

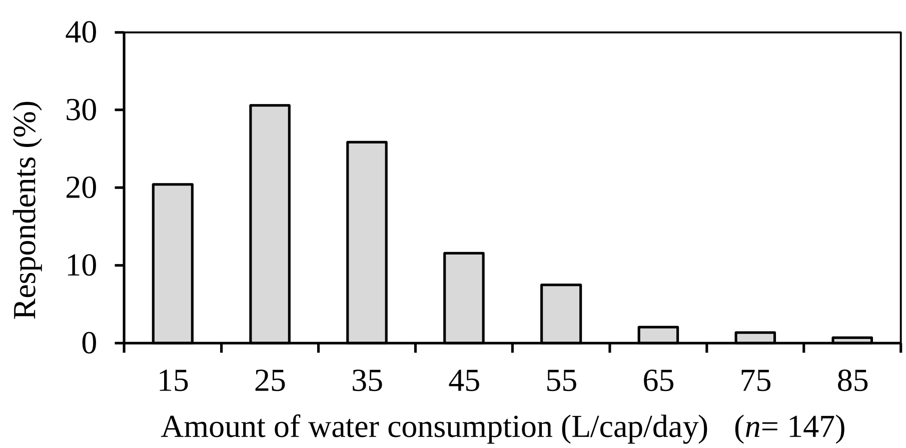


Figure 4.1 Distribution of water consumption of households

Figure 4.2 summarizes total volume of water consumed (L/cap/day) across different water supply source combination users. Median water consumption of households combining private connection, bottled water and tanker was above 50.0 L/cap/day, while for others it was below the minimum recommended value. Total water consumption of households using households combining private connection, private well and tanker (55.9 L/cap/day) were found to be the largest, followed by households combining private well and tanker users (39.3 L/cap/day), while those using only private connection was the lowest (15.0 L/cap/day).

The higher amount of water consumption among private well users can be attributed to free and 24 hours accessibility of the source. The low amount of water consumption for private pipe connection users can be attributed to intermittent and insufficient piped water supply.

In case of public standpipe users, total water consumption was quantified for only households carrying water from the sources to their residence. Therefore, inconvenience for carrying water from distant source could have been possible reason for low water consumption among public standpipe. Few households located closer to public standpipe and community supply sources were found to use electric motor to pump water from those

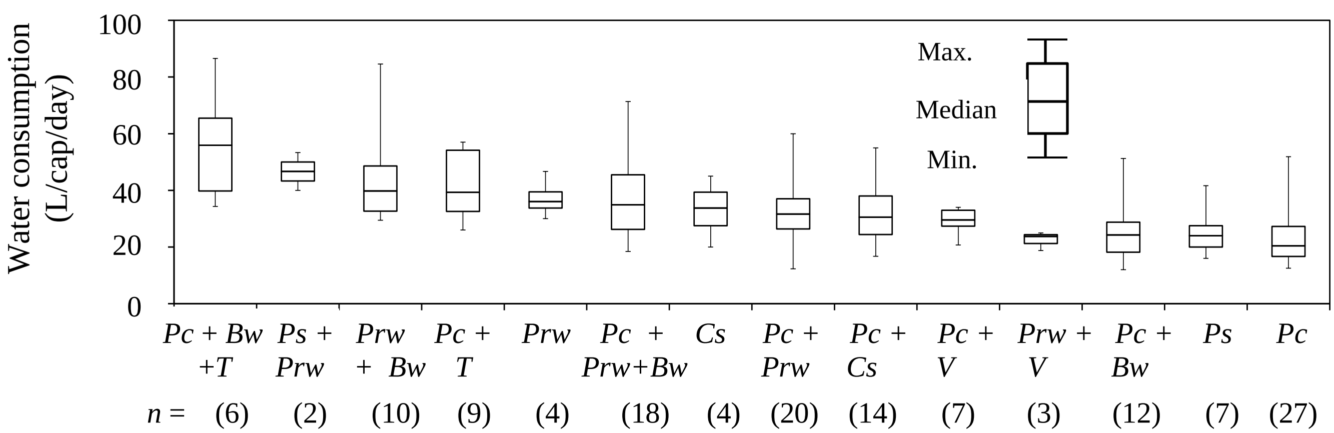


Figure 4.2 Comparison of total water consumption across different water sources users

Note: Sources combinations were arranged in descending order of their median total consumption value

Pc: Private pipe connection, *Prw*: Private well, *Bw*: Bottled water, *T*: Tanker, *V*: Vendors, *Cs*: Community sources, *Ps*: Public standpipe, *Pw*: Public well, *n*: sample size for each water supply sources combination water supply sources to their residence. It was more convenient to transport water from the source to the residence for households located closer to outdoor supply sources (*i.e.* community sources, vendor and public standpipe), as a result they had higher water consumption than those farther.

In chapter 3, it was discussed that different water supply sources were used for different purposes. In the following section, influence of water supply sources on amount of water consumption for potable and non-potable purposes has been described.

Figure 4.4 shows the amount of water consumed for potable purposes (drinking and cooking). Based on questionnaire survey, average ± standard deviation volume of water consumption for potable purpose was 6.2 ± 2.6 L/cap/day. Households combining private well with bottled water was found to have the highest average water consumption (7.5 ± 3.3 L/cap/day) for potable purposes. Those households used bottled water for drinking and private well for cooking purpose. Though the cost of bottled water was high but private well could be used freely, therefore probably higher amount of water was consumed for cooking purpose. Households using vendor was found to have lowest average water consumption (4.2 ± 1.3 L/cap/day) for potable purposes.

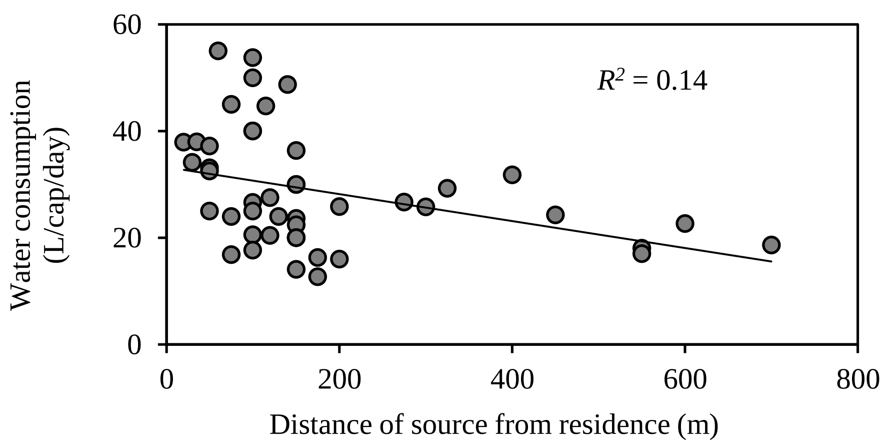


Figure 4.3 Relationship between water consumption and distance of outdoor sources from residence

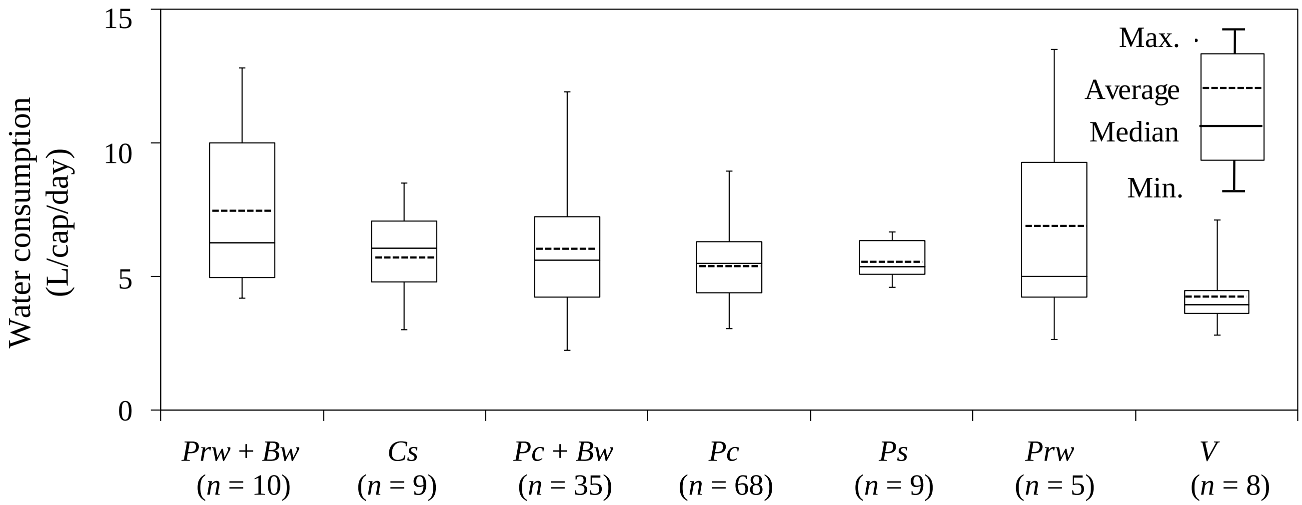


Figure 4.4 Comparison of water consumption for potable purposes across different water sources users

Note: Sources combinations were arranged in descending order of their median values of a group

Pc: Private pipe connection, *Prw*: Private well, *Bw*: Bottled water, *T*: Tanker, *V*: Vendors, *CS*: Community sources, *Ps*: Public standpipe

Figure 4.5 shows the amount of water consumed for non-potable purposes (other than drinking and cooking). The average ± standard deviation water consumption for non-potable purpose was 26.4 ± 12.1 L/cap/day. Tanker and private well users were found to have the highest average water consumption (38.9 ± 9.5 L/cap/day), while the vendor users had the lowest (19.3 ± 7.2 L/cap/day). As discussed above, higher amount of water consumption among tanker and private well users can be inferred to higher living standard of tanker users and 24 hour accessibility of private well users. The possible reason for lower water consumption among vendor users could be due to higher cost of the source (NRs 300/m^3). Also, in **Table 3.11** it was shown that households with low income (other than community sources and public standpipe) had tendency to use vendor for non-potable purposes.

4.3.2. Water using behavior

Water using behavior is one of the important variables that determine water consumption (Zhang and Brown, 2005). Therefore, to determine the influence of water using behavior on water consumption, respondents were asked about frequency of bathing, laundry and water saving initiatives viz. reduction in frequency of laundry and bathing, gray water use and installation of water efficient retrofit.

Only 45.2 % of total respondents (n = 217) were found to use tap for bathing, while remaining respondents (54.8%) stated that they collected water in bucket, then used bowl and jugs to withdraw water from bucket and to pour water over themselves. Hand washing was reported as the common method of laundry for 93.8% of total respondents.

Frequency of bathing and laundry was found to be significantly (p < 0.001) between summer (Apr. - Oct.) and winter (Nov. - Feb.) seasons as shown in **Fig. 4.6 (A)** and **(B)**. In an average ± standard deviation, frequency of bath in summer was 3.2 ± 1.3 times/week, which decreased to 1.4 ± 0.5 times/week. The frequency of laundry in summer decreased from 2.1 ± 0.9 times/week to 1.3 ± 0.6 times/week in winter. **Figure 4.7** shows the

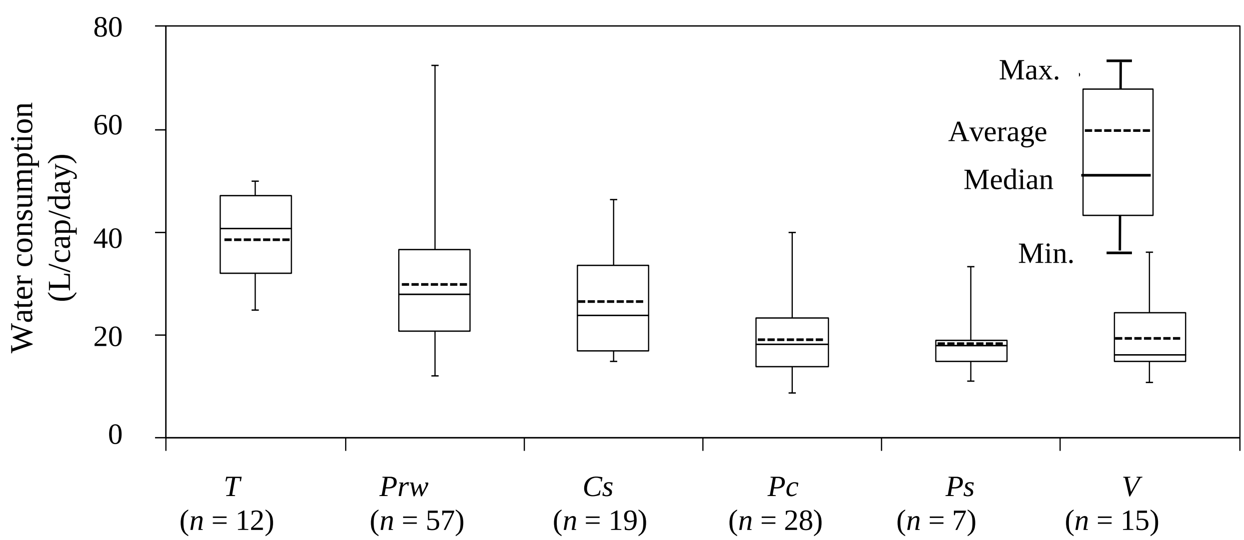


Figure 4.5 Comparison of total water consumption for non-potable across different water sources users

Note: Sources combinations were arranged in descending order of their median values of a group

Pc: Private pipe connection, *Prw*: Private well, *T*: Tanker, *V*: Vendors, *Cs*: Community sources, Ps: Public standpipe relationship between water consumption of households for non-potable uses and frequency of bathing in winter. The median amount of water consumption of households bathing only 1 time/week was 19.1 L/cap/day, while those bathing 7 times/week was 65.3 L/cap/day. The possible reason for lower water consumption of households in Kathmandu valley than other cities can be related to low frequency of bath and laundry.

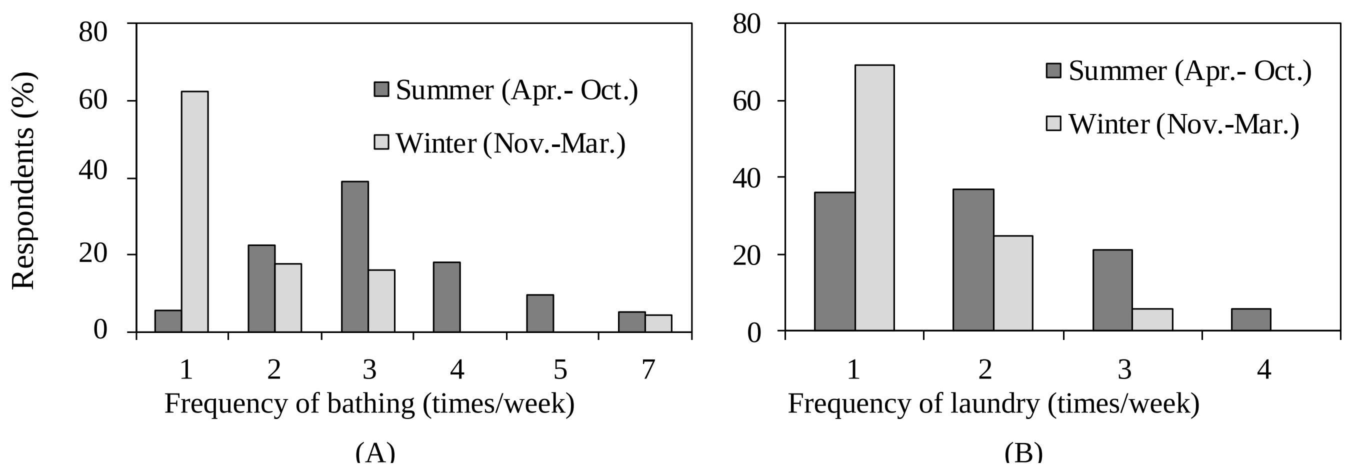


Figure 4.6 Frequency of (A) bathing (B) laundry during summer and winter season

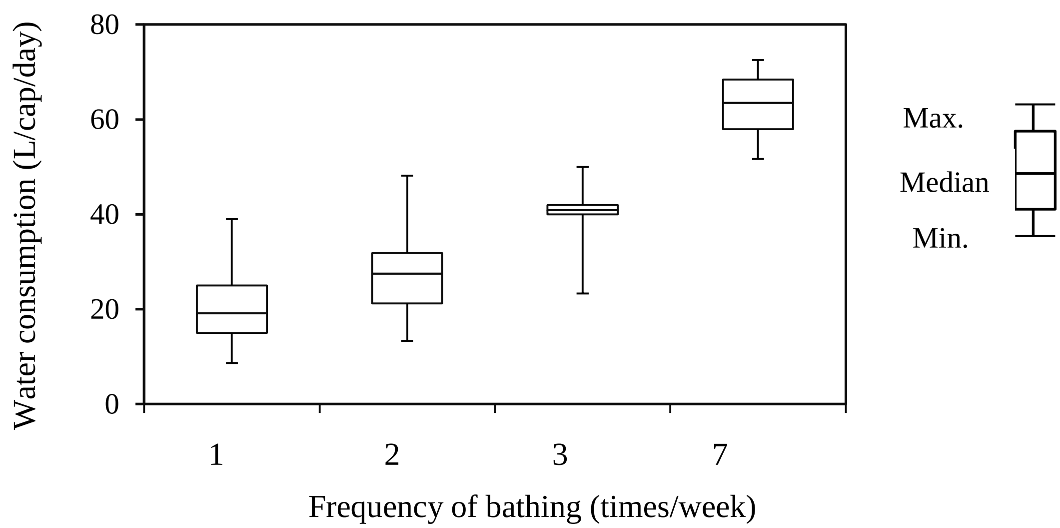


Figure 4.7 Relationship between water consumption for non-potable uses and frequency of bathing (winter)

Moreover, water consumption of households in summer can be expected to increase with increase in frequency of bath during the season. The frequency of bath during winter season was found to be positively correlated (r = 0.34, p < 0.001) with possession of water heaters.

Consumer index (*CI*) was summation of six water conservation practices *i.e.* reduce frequency of bath and laundry, gray water use for gardening, toilet flushing and gardening and installation of efficient retrofits. Though theoretically the value of CI ranges from 0 to 6, but the calculated values ranged from 0 to 4. **Table 4.2** shows the proportion of respondents using different water conservation measures. The majority of households (83.4%, n = 217) were found to adopt at least one water conservation measures. The higher proportion of respondents were found to reduce frequency of bath (53.4%, n = 217) and laundry (50.7%, n = 217) for reducing water consumption, while installation of water efficient retrofits was reported by minimal number of respondents (2.3%, n = 217).

Average ± standard deviation consumer index of households was 2.0 ± 1.2. **Figure 4.8** shows water consumption of households having different consumer index score. The median amount of water consumption for households not adopting any water conservation measures was 31.7 L/cap/day, while it was 15.0 L/cap/day for households adopting 4 different water conservation measures. The amount of water consumption was found to

Table 4.2 Frequency of respondents adopting water conservation measures

Water saving measures	Respondents (%)
Reduce frequency of bath	53.4
Reduce frequency of laundry	50.7
Gray water use for toilet flushing	29.5
Gray water use for gardening	20.7
Gray water use for laundry	9.2
Install water efficient retrofit	2.3

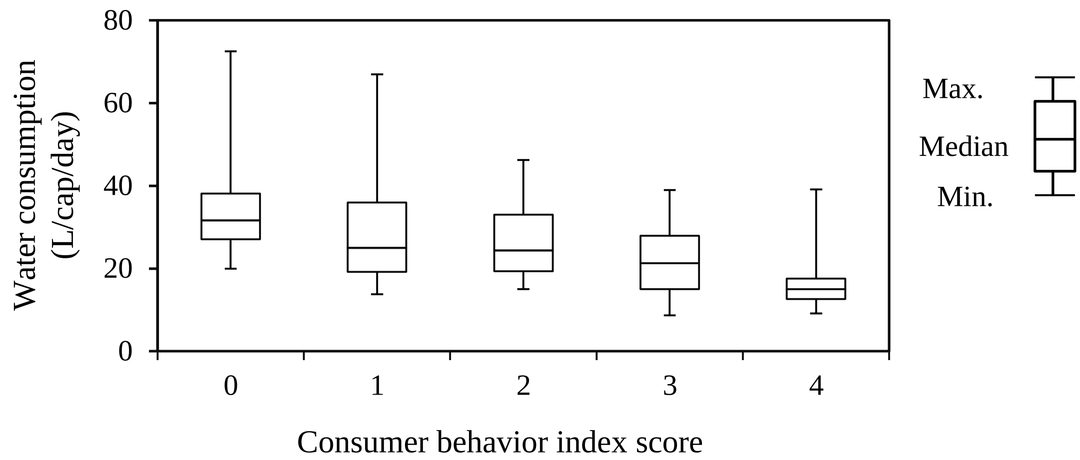


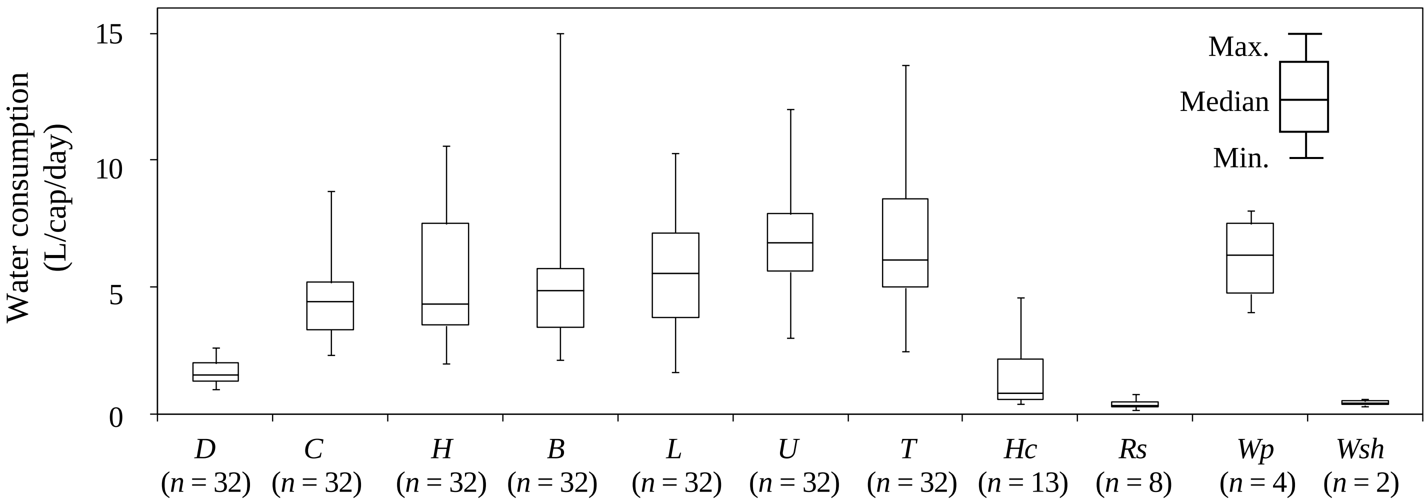
Figure 4.8 Influence of water conservation measures on water consumption

be statistically different at significant level (p < 0.001, Kruskal Wallis test) across *CI* score. This further elucidates the reason for low amount of water consumption for households in Kathmandu valley. Water conservation measures have been reported to reduce water consumption of households in other cities as well (Zhang and Brown, 2005; Fan *et al.*, 2013) and changes in living styles and increase in water availability may increase water consumption in future.

4.3.3. Micro-component analysis of water consumption

Based on diary method, daily micro-components of water consumption of 32 households were measured for a week. The median value of all micro-components of water consumption was lower than minimum value stated by Gleick (1998), as shown in **Fig. 4.9**.

Based on median value, the highest amount of water was consumed for dishwashing (6.8 L/cap/day), followed by toilet use (6.6 L/cap/day). Out of 32 households, 75.0% of them used pour flush toilet, followed by single and double flush by 15.6% and 9.3% of households, respectively. The average ± standard deviation amount of water used per flush after excretion was 5.2 ± 2.7 L and it was 1.3 ± 0.9 L per flush after urination.



Note: *D*: Drinking, *C*: Cooking, H: Hygiene, *B*: Bath, *L*: Laundry, *U*: Dish washing, *T*: Toilet, *Hc*: House cleaning, *Ra*: Religious activities, *Wp*: Watering plants, *Wsh*: Car and bike washing

Figure 4.9 Micro-components of water consumption of households

The median value of amount of water consumed per bathing was 25.1 L/capita, while it was 30.0 L/capita for water consumed per laundry. Since, households did not bath or laundry every day, thus water consumed for bathing and laundry per day was reduced to only 4.9 L/cap/day and 5.5 L/cap/day. The amount of water consumed for each activity was lower than those reported by Otaki *et al.* (2008) for Chiang Mai and Bangkok. Earlier it was discussed that frequency of bath and laundry increased during summer (Apr. – Oct.), thus water consumption can be expected to increase during season. In this study, micro-components of water consumption were measured only during winter (Nov. – Mar.).

These households were categorized into three groups based on their monthly income *viz.* low income (NRs < 15,001), medium (NRs 15,001- 30,000) and high (> NRs 30,000) as summarized in **Fig. 4.10**. The total water consumption of low income groups was 22.2 ± 2.1 L/cap/day, while medium and high income groups consumed 35.3 ± 6.8 L/cap/day and 52.9 ± 9.5 L/cap/day, respectively (**Fig. 4.11**). Water consumption for cooking, laundry, dishwashing and bathing was significantly ($p < 0.05$) different across three income groups (**Fig. 4.12**). The average amount of water consumed for hyginene and bathing was less than the minimum required value of 10.0 L/cap/day and 15.0 L/cap/day, respectively across all income groups. It can be inferred than low- and medium-income groups had ben coping with water shortages by reducing their water consumption for bathing.

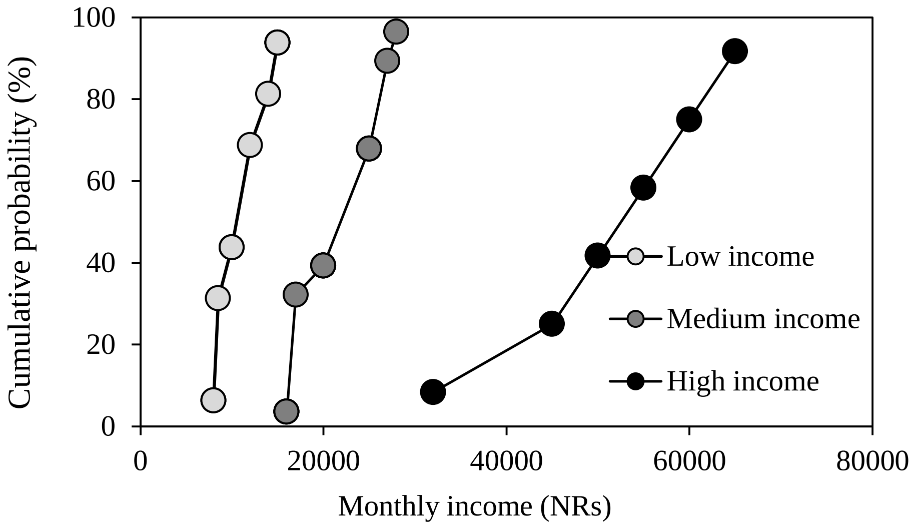


Figure 4.10 Distribution of income groups

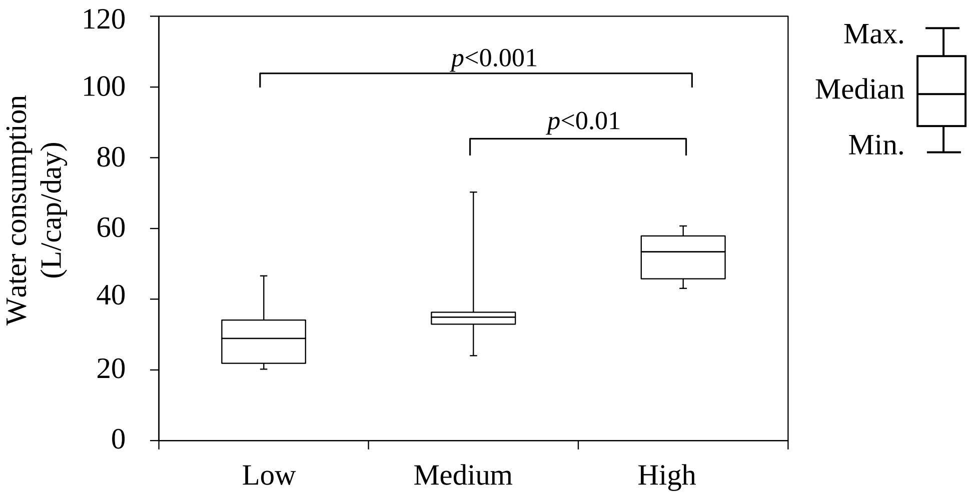


Figure 4.11 Total water consumption for different income groups based on diary method (L/cap/day)

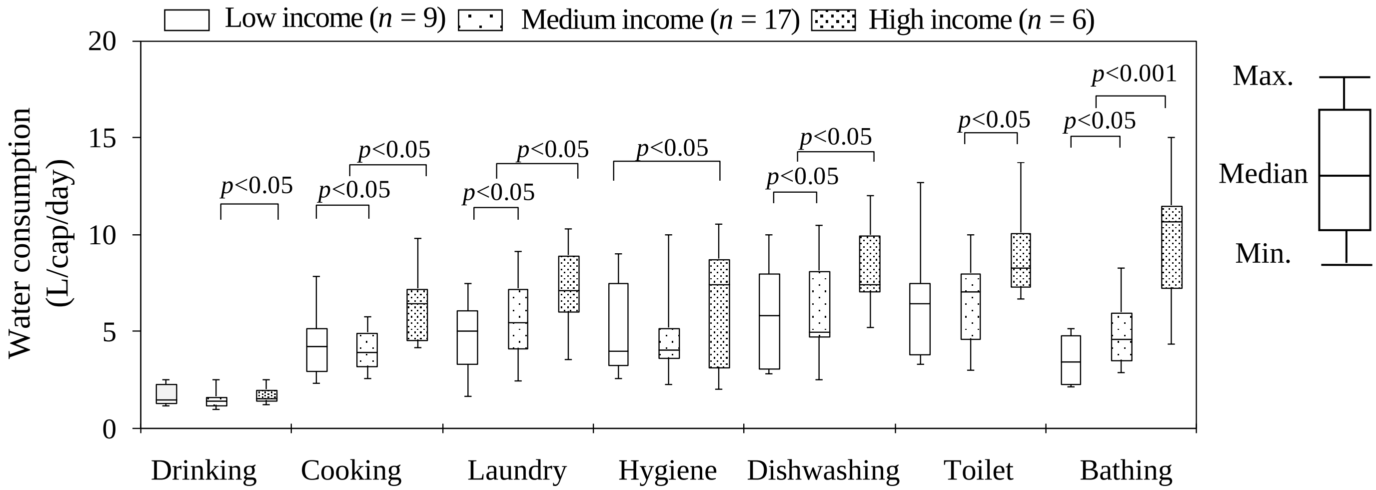


Figure 4.12 Comparison of micro-component water consumption across income groups

Figure 4.13 shows the amount of water consumption for different water supply sources users. Households using only private piped connection had the lowest amount of water consumption, while those using private well or tanker had the highest amount of water consumption. Despite availability of private well, some households were found to consume higher volume of water from tanker because the former source was reported to have poor quality.

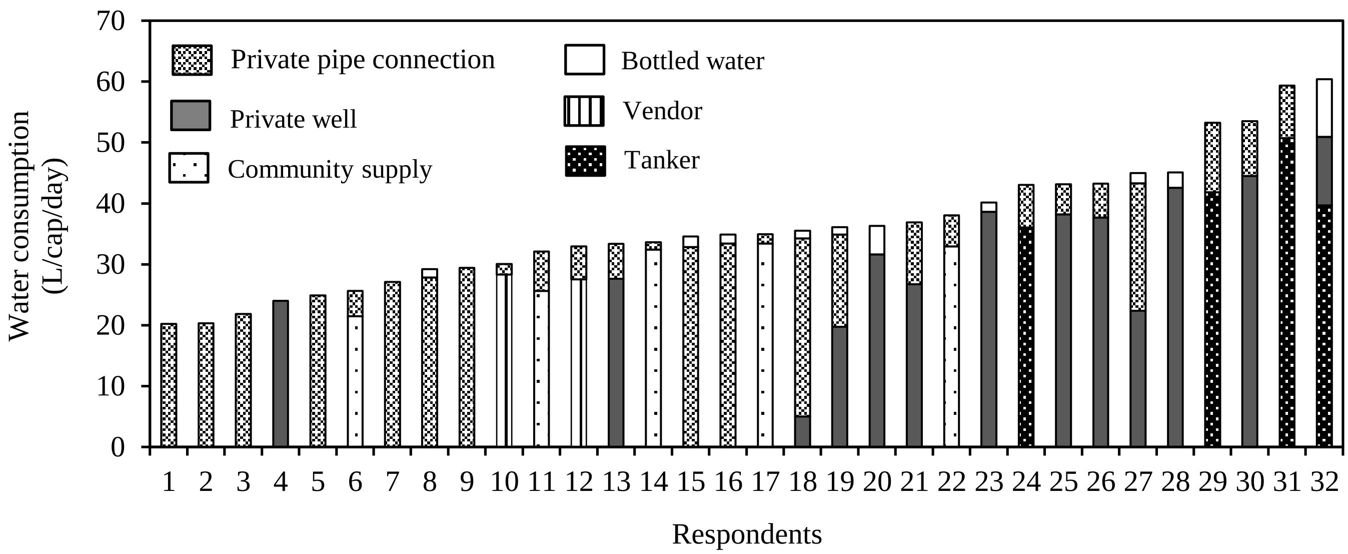


Figure 4.13 Amount of water consumption for different supply sources users

4.3.4. Factors influencing water consumption

In this section, we analyzed factors influencing water consumption for potable and non-potable uses. In order to avoid multi-collinearity problem, correlation was done between independent variables and also with dependent variable (per capita water consumption). If correlation coefficient between two independent variables was above 0.3, only the independent variable having high correlation coefficient with dependent variable was used for regression analysis.

Housing ownership and size of water storage capacity of households was found to have medium to high correlation with monthly income of households as shown in **Table 4.3** and **4.4**. The monthly income of households was also found to have high correlation with possession of water heater. The proportion of members below 15 years and adults (> 15 < 60 years old) were found to have high correlation with proportion of elderly members (above 60 years old). Since the correlation coefficient between monthly income and total water consumption was higher than between total water consumption and variables such as size of storage tank water heater, and housing ownership; therefore monthly income was selected for regression analysis in favor of other variables for regression analysis. Similarly, correlation between total water consumption and elderly member of households was higher than other age

Table 4.3 Correlation coefficient between independent variables for potable use model

		1	2	3	4	5	6	7	8	9	10	11	12
1	Water consumption	1											
2	Monthly income	0.48***	1										
3	Education	0.09	0.24**	1									
4	[a]Housing ownership	0.21***	0.39***	-0.13	1								
5	Family size	-0.08	0.12	0	0.19	1							
6	Proportion of male	-0.15	-0.23*	-0.05	-0.14	-0.16	1						
7	Size of storage tank	0.35**	0.66***	0.18*	0.52***	0.11	-0.11	1					
8	Proportion of members below 15	-0.15**	-0.23	-0.08	-0.21	0.31***	-0.02	-0.21	1				
9	Proportion of members >15<60	-0.18	-0.12	0.04	-0.07	-0.44***	0.12	-0.06	-0.68**	1			
10	Proportion of members >60	0.43**	0.23**	0.01	0.32**	0.22	-0.13	0.32*	-0.22	-0.53**	1		
11	Occupants	-0.1	-0.02	0.1	-0.18	0.12	-0.05	0.08	-0.03	0.04	-0.05	1	
12	[a]Bottled water user	0.41***	0.20***	0.24**	0.14	0.01	-0.08	0.14	-0.22	-0.07	0.25***	-0.04	1

Note: [a]Dummy variables (***: p<0.001), (**: p<0.01), (*: p<0.05)

Table 4.4 Correlation coefficient between independent variables included in the models for non-potable use

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Water consumption	1														
2	Monthly income	0.52**	1													
3	Education	0.06	0.24	1												
4	[a]Housing ownership	0.19***	0.39***	-0.13	1											
5	Family size	-0.16*	0.12	0	0.19	1										
6	Proportion of male	-0.14	-0.23	-0.05	-0.14	-0.16	1									
7	Size of storage tank	0.43***	0.66***	0.18**	0.52***	0.11	-0.11	1								
8	Proportion of members below 15	-0.19*	-0.23*	-0.08	-0.21***	0.31***	-0.02	-0.21**	1							
9	Proportion of members >15<60	-0.05	-0.12	0.04	-0.07	-0.44***	0.12	-0.06	-0.68***	1						
10	Proportion of members >60	0.31**	0.4	0.01	0.32	0.22	-0.13	0.32**	-0.22*	-0.53*	1					
11	Occupants	0.02	-0.02	0.1	-0.16**	0.12	-0.05	0.08	-0.03	0.04	-0.05	1				
12	Frequency of bathing	0.64**	0.29	0.13	0.16	-0.1	-0.05	0.37***	-0.21***	-0.02	0.27**	0	1			
13	Frequency of laundry	0.30***	0.27	0.06	0.3	0.09	-0.02	0.34**	-0.21*	-0.02	0.27**	-0.02	0.29	1		
14	Consumer Index	-0.15	-0.14	0.09	-0.17	0.01	0.12	-0.13	0.01	0.12	-0.15	0.01	-0.17	-0.09	1	
15	[a]Private well users	0.30***	0.26	0.22***	-0.11	0.12	-0.04	0.04	-0.12	0.04	0.07	0.19**	0.28	0.16*	-0.07	1

Note: [a]Dummy variables, (***: $p<0.001$), (**: $p<0.01$), (*: $p<0.05$)

group members; hence only elderly member of households was selected for regression analysis.

Table 4.5 shows summary of independent variables used for regression analysis. **Table 4.6** shows factors influencing water consumption for different supply sources. The performance of models, except for the community sources users was satisfactory. The regression model for private pipe connection and tanker users explained more than half of variation in water consumption.

Monthly income was found to be the major explanatory factor for both potable and non-potable water consumption. Income indicates living standard of the households. Therefore, household with larger income may use more water to maintain proper hygiene and also for amenities such as gardening. It is assumed that poverty negatively affects water use because poor people cook less and often have less clothing to wash (Sandiford *et al*., 1990).

Table 4.5 General description of independent variables (n = 147)

	Minimum	Average (SD)	Maximum
Monthly income (NRs in thousands)	5.0	19.5 (12.5)	70.0
Education of household head (years)	0.0	11.7 (4.3)	17.0
Family size (person)	2.0	4.0 (1.5)	12.0
Proportion of male (%)	20.0	50.0 (15.4)	100.0
Proportion of members above 60 years (%)	0.0	8.1 (14.8)	66.7
Number of occupants (person)	3.0	10.0 (4.0)	22.0
Frequency of bathing (times/week)	1.0	1.7 (1.0)	7.0
Frequency of laundry (times/week)	1.0	1.3 (0.5)	3.0
Consumer behavior index	0.0	1.9 (1.3)	4.0

Household size was found to be significant for both potable and non-potable purposes. Per capita water consumption for larger household size was low compared to smaller households' size. Household activities such as cooking and laundry are done for whole family rather than for an individual; however these economies of scales for water use may not be applicable to small sized households. Though increase in number family member may increase total consumption but reduced per capita consumption (Butler, 1993). Moreover, water consumption may be expected to increase with growth of number of households rather than population growth (Keshavarzi *et al*., 2006).

Proportion of elderly members (above 60 years old) was found to be significant predictor for potable water consumption. The probable reason could be that elderly members spend more time at house and possibly frequency of meals at house may be higher for households with elderly members than those belonging to other age groups. Therefore, they consume more water for drinking as well as for cooking. Frequency of bathing and consumer behavior index (*CI*) were significant predictors for amount of water consumed for non-potable purposes. Frequency of bathing was found to have positive effect, while

Table 4.6 Factors influencing water consumption for potable and non-potable purposes

Independent variables	Potable purposes			Non-potable purposes		
	[a]Unstd. Coeff.	[b]Std. Coeff.	*p* value	[a]Unstd. Coeff.	[b]Std. Coeff.	*p* value
Constants	-0.03		NS	0.62		*
Log. monthly income	0.20	0.31	***	0.24	0.28	***
Education	0.001	0.03	NS	-0.004	-0.09	NS
Family size	-0.02	-0.18	*	-0.02	-0.18	*
Proportion of male	-0.001	0.07	NS	-0.001	-0.07	NS
Proportion of members above 60 years	0.003	0.26	**	0.001	0.05	NS
Number of occupants	0.003	0.05	NS	0.003	0.05	NS
Frequency of bathing	-	-	-	0.08	0.42	***
Frequency of laundry	-	-	-	0.01	0.04	NS
Consumer behavior index	-	-	-	-0.03	-0.21	**
Bottled water users	0.07	0.20	*	-	-	-
Private well users	-	-	-	0.03	0.08	NS
Adjusted R^2	0.36			0.56		

Note: Only significant variables were shown in table
[a]Unstandardized coefficients [b]Standardized coefficients

consumer behavior index had negative effect on amount of water consumed for non-potable purposes. Zhang and Brown (2005) also found that frequency of bathing positively correlated with water consumption. Households using bottled water were found to have tendency to consume more water for potable purposes.

4.4. Summary

Total average water consumption of households in Kathmandu valley was 32.3 L./cap/day, which was lower than minimum recommended value of 50.0 L/cap/day. Similarly, micro-components of water consumption were found to be lower than recommended values. The total amount of water consumption of households using different supply sources were found to vary significantly.

Households using private well and tanker were found to have significantly higher water consumption than households using only private piped connection or public standpipe or community sources. Free and easy accessibility of private well can be attributed to high consumption among private well users. Water consumption pattern was found to vary among different income groups. Thus, this variation has to be accounted for water demand management. Monthly income and family size of households were found to be significant predictors of water consumption for both potable and non-potable purposes. Other predictors for potable purposes were proportion of elderly members and bottled water users, and predictors for non-potable purposes included frequency of bathing and consumer index.

Chapter 5

Microbiological water quality assessment

5.1. Introduction

Due to its impact on public health, microbiological quality of drinking water has attracted great attention worldwide. It is the major cause of water borne diseases (diarrhea, dysentery, typhoid fever, hepatitis etc.) in many developing countries. Many developing countries in Asia, including Nepal have increased their drinking water supply coverage. However, total coliform and *Escherichia coli* in the water samples collected from water sources have been detected. This has caused frequent outbreak of various waterborne diseases in urban and rural areas of Nepal.

As discussed in chapter 3, households were found to use multiple water supply sources *i.e.* piped water, bottled water, tanker, vendor, well and stone spouts for different purposes and also store water in different types of storage tanks. Contamination of water during collection and storage has been reported (Trevett, *et al*., 2005), though attenuation of indicator organisms have also been observed (Levy *et al*., 2008). Moreover, there is no consensus on effect of types of storage tanks and water handling behavior of water during collection and storage. Consumption of contaminated water will increase health risks, thus monitoring of water quality at the sources and at point of use is essential for not only preventing diseases but also to improve and protect sources from further water quality degradation. Therefore specific objectives of this chapter are as follows:

(a) To determine effectiveness of water treatment plant to remove microbial organisms,
(b) To investigate microbial water quality of different water supply sources and at point of uses

(c) To quantify annual exposure to fecal bacteria from consumption of contaminated water

5.2. Materials and Methods

5.2.1. Samples collection

Water samples were collected and kept in airtight large plastic ice-cold containers and were transported to laboratory within 6 h of their collection for further processing. The samples were collected from inlet (raw water) and outlet (treated water) from 8 water treatment plants as shown in **Fig. 5.1**. For understanding water contamination during water distribution, a water sample was collected from private pipe connection (tap) of each water treatment plants.

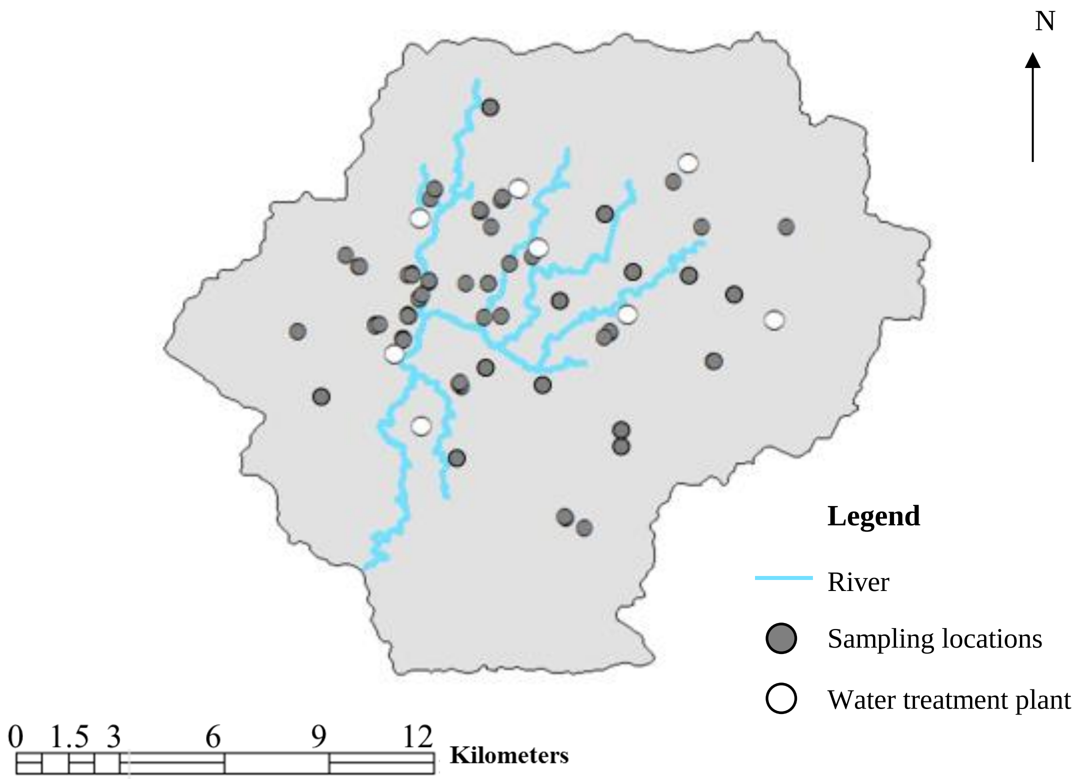


Figure 5.1 Location of water treatment plant and sampling sites

For understanding pathways of water contamination at household level, 252 water samples, each 100 mL, (i) from water supply sources (97 samples) , (ii) from storage tanks (111 samples) (iii) household treated water (67 samples) and (iv) post water treatment (15 samples) as shown in **Figure 5.2** were collected. The survey was conducted in April-May 2012 and February 2013 in Kathmandu valley.

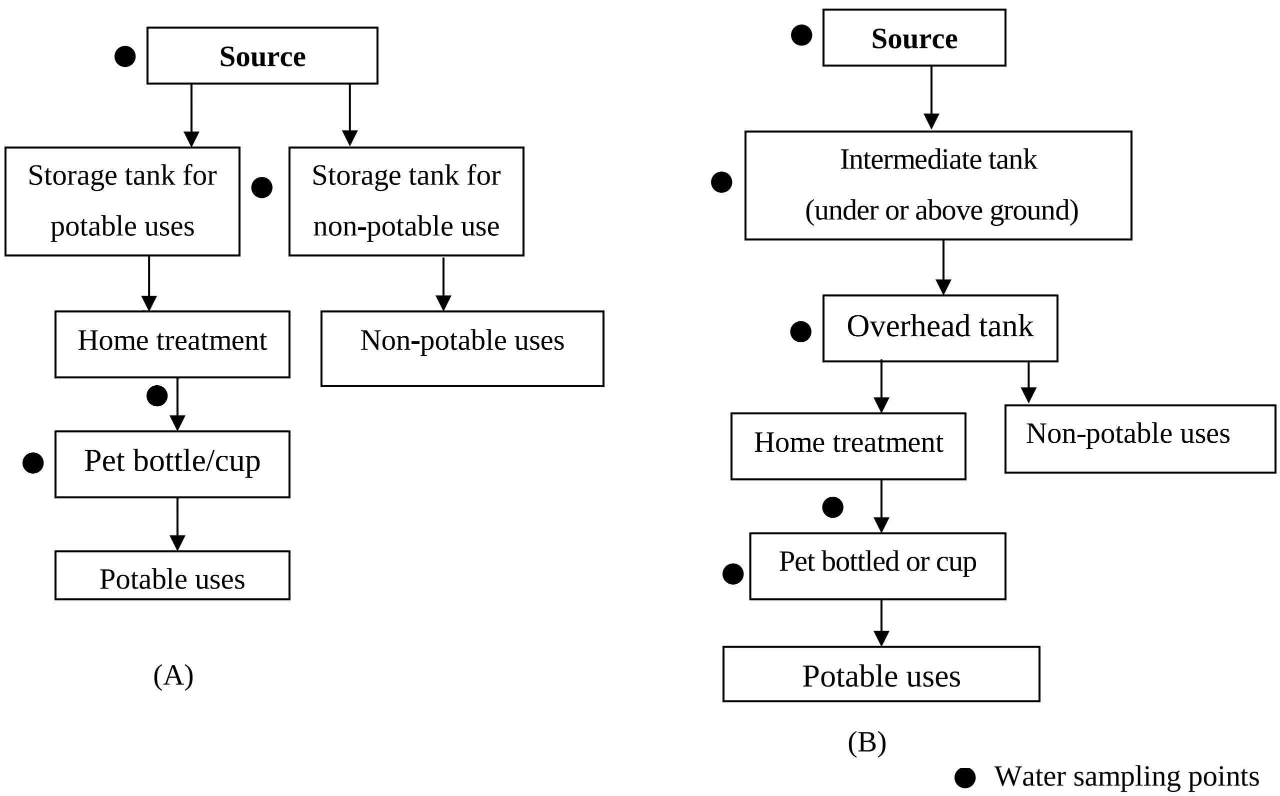


Figure 5.2 Sampling points in a household (A) without overhead tank (B) with overhead tank

5.2.2. Method of water quality analysis

Total coliform and *E. coli* were enumerated using membrane filtration techniques, Standard Methods 9222D and 9230C, respectively (APHA, 1998). Depending on bacterial load appropriate volume of water samples (1–1500 mL) were filtered through 0.45 µm cellulose membrane filters and transferred onto Chromocult® coliform agar (Merck KGaA, Darmstadt, Germany) plates, and incubated for 24 hours at 37 °C. Each sample was triplicated. ChromoCult® allows the selective detection of coliforms and distinguishes *E. coli* in a heterogeneous bacterial community, as its colonies appear in a characteristic dark-blue to violet color (Merck, 2004).

5.2.3. Household interview survey

A structured interview survey was conducted during April-May, 2012 and February, 2013. For this survey, 79 households were selected from urban zone of Kathmandu valley and they were interviewed about their water supply source, methods of treatment, size of water storage tank etc. as shown in **Table 5.1** (see **Appendix II** for detailed information). It took about 10 minutes to complete the questionnaire.

Table 5.1 Contents of the questionnaire

Theme	Type of question	Reference
1) Water supply sources , their uses and facilities	Water supply sources	Figure 5.6
	Methods of water treatment	Table 5.2
	Type of water storage container, location of container, Covered or uncovered, frequency of cleaning,	Figure 5.7

5.2.4. Data analysis for exposure assessment

In this chapter, the amount of fecal bacteria ingested by different water supply sources users was estimated. For this purpose, following ways of water intake were considered:

a) Direct intake for drinking
b) Indirect intake during bathing
c) Indirect intake during teeth brushing and mouth rinsing

The amount of water consumed for drinking was obtained from chapter 4. It was estimated as 1.6 L/cap/day, which fitted well with lognormal distribution. Dufor *et al*., (2006) estimated that non-adults and adults intake 37 mL and 16 mL of water during swimming. In this chapter, it was assumed that 26.5 mL (average of non-adults and adults) of water was swallowed during bathing.

For estimating amount of water swallowed during teeth brushing and mouth rinsing, 18 respondents were selected. At first, each respondent was requested to rinse mouth to remove any food particles remaining in the mouth. Then, the amount of water consumed for teeth brushing and mouth rinsing was measured for each respondent, using a plastic cup and a measuring scale. Then, each respondent was requested to rinse their mouth with the measured volume of water and to spit in another plastic cup. For estimating amount of water swallowed during mouth rinsing, weight of spitted water was deducted from weight of water for mouth rinsing as shown in Eq. 1. The weight of plastic cups were nullified before measuring weight of water for mouth rising and spitted water. For each respondent, this process was repeated three times. Though, spitted water may contain some amount of saliva as well but it is assumed to be minimal and hence neglected.

$$V_s = V_{mr} - V_{st} \qquad \text{Eq. 1}$$

Where, V_s stands for volume of water swallowed during teeth brushing and mouth rinsing (mL), and V_{mr} and V_{st} stands for volume of water used for mouth rinsing and spitted water (mL), respectively.

The suitable probability density functions (PDFs) for water quality data were selected based on Kolmogorov-Smirnov test. Crystal Ball 11 (Oracle) was used for PDF fitting and calculation. Exposure of households to contaminated water was calculated as shown in Eq. 2.

$$E = (C * Wd * 1000 * 365) + (C * Wt * 365) + (C * Ws * 365) \qquad \text{Eq. 2}$$

Where, *E* stands for total annual exposure (CFU/year); *C* stands for concentration of *E. coli* (CFU/1mL) and *Wd*, *Wt*, *Ws* stands for amount of water consumed for drinking, teeth brushing and mouth rinsing and shower (mL), respectively.

5.3. Results and Discussions

5.3.1. Water quality at water treatment plant

Electrical conductivity of water samples from intake of treatment plant ranged from 75-220 µS/cm, while for treated samples it was 41-172 µS/cm. Similarly, pH of water samples at intake of treatment plant ranged from 6.9-7.8 and for treated samples it was 7.1 -8.0.

Total coliform and *E.coli* were detected in all the raw water samples collected from water treatment plants as shown in **Fig. 5.3**. The highest number of indicator organisms was detected in raw water collected from Balkhu (*Ba*) *WTP*, while the least from Sainbu (*Sa*) *WTP*. During sampling, only surface water was treated by all treatment plants, though after

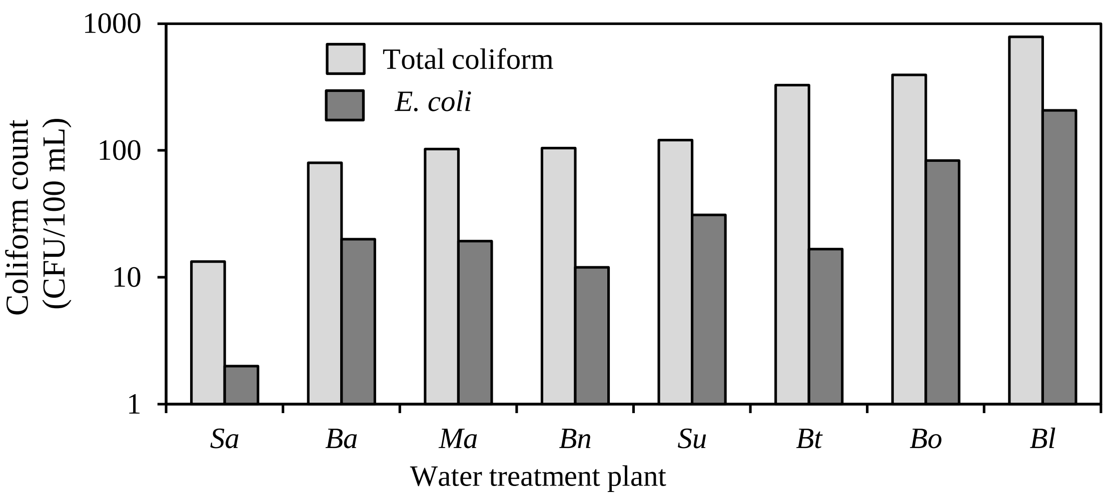


Figure 5.3 Coliform counts at inlet of different water treatment plants

Note: WTPs are arranged in ascending order of total coliform counts

Sa: Saibu WTP, *Ba:* Balaju WTP, *Ma*: Mahankal WTP, *Bn*: Bansbari WTP, *Su*: Sundarijal WTP, *Ba* Bhaktapur WTP, *Bo:* Bode WTP, *Bl*: Balkhu WTP

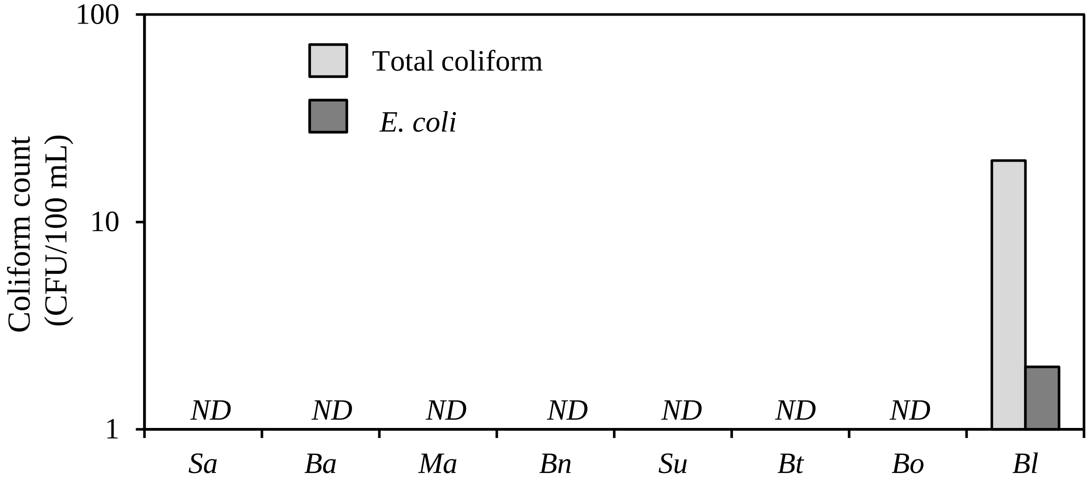


Figure 5.4 Coliform counts of treated water at outlet of different water treatment plants

Note: *Sa*: Saibu WTP, *Ba:* Balaju WTP, *Ma*: Mahankal WTP, *Bn*: Bansbari WTP, *Su*: Sundarijal WTP, *Ba* Bhaktapur WTP, *Bo:* Bode WTP, *Bl*: Balkhu WTP, ND: Not detected

March they supply ground water as well. Total coliform and *E.coli* were not detected in treated water samples except for BL WTP as shown in **Fig. 5.4**. All these water treatment plants treated water using slow sand filtration method, except *Bl* WTP which used pressure filter method.

5.3.2. Water quality of tap water from different water treatment plants

As shown in **Figure 5.5**, total coliform were detected at tap of piped water connection of individual houses, though they were not detected at the outlet of water treatment plants. This shows that water contamination happens during process of water distribution. *Ma*1 and *Ma* 2 were samples collected from Mahankal (*Ma*) water treatment plant but were at different distance. *Ma* 1 was located at distance of 2 km. from *WTP*, while *Ma* 2 was located at distance of 3.4 km. from *WTP*. Though sample size is not enough to conclude contamination increases with distance from *WTP*, however it shows increasing trend of contamination with distance.

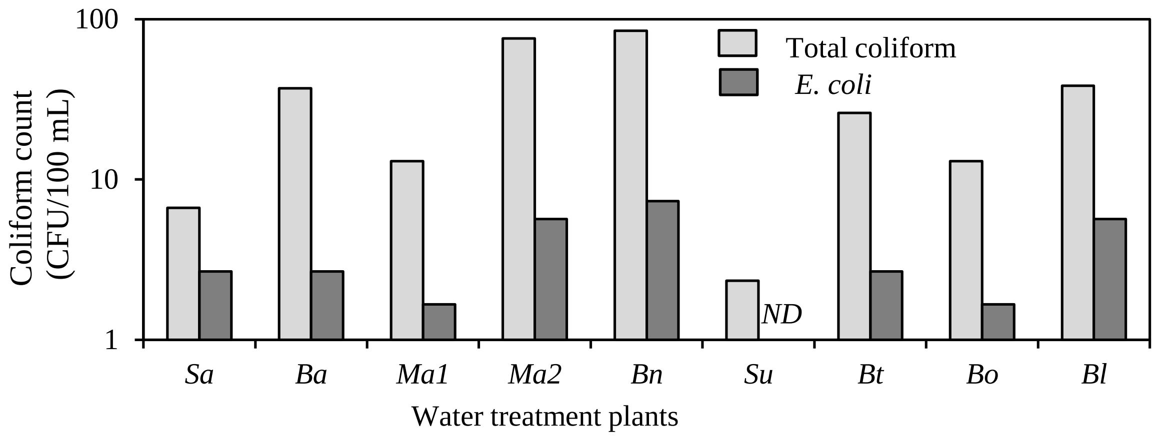


Figure 5.5 Coliform counts of distributed tap water from different water treatment plants

Note: *Sa*: Saibu WTP, *Ba:* Balaju WTP, *Ma*: Mahankal WTP, *Bn*: Bansbari WTP, *Su*: Sundarijal WTP, *Ba* Bhaktapur WTP, *Bo:* Bode WTP, *Bl*: Balkhu WTP, *ND*: Not detected

5.3.3. Water quality of different water supply sources

Figure 5.6 shows concentration of total coliform and *E.coli* for different water supply sources. The microbial contamination was found to be the highest for community sources, followed by shallow wells (<50 m). The water supply sources were found to be significantly different ($p < 0.001$). Warner *et al.*, (2003) also found that shallow wells and community sources were more contaminated than other water supply sources and suggested that possible source of contamination could be poor sewage system. Earlier in chapter 3, it was found that households having low income and low educated head use community sources for drinking purpose. Since it was found to be a contaminated source, low educated and low income households are at greater health risk than other sources users.

Total coliforms were detected in 100% of samples, except for bottled water. However, total coliforms were detected in the majority of bottled water (54.4%, n = 11) ranging from 2-125 CFU/100 mL. As discussed in chapter 3, households used bottled water because they perceived their sources as free from impurities, however contamination was detected and this has serious health consequences.

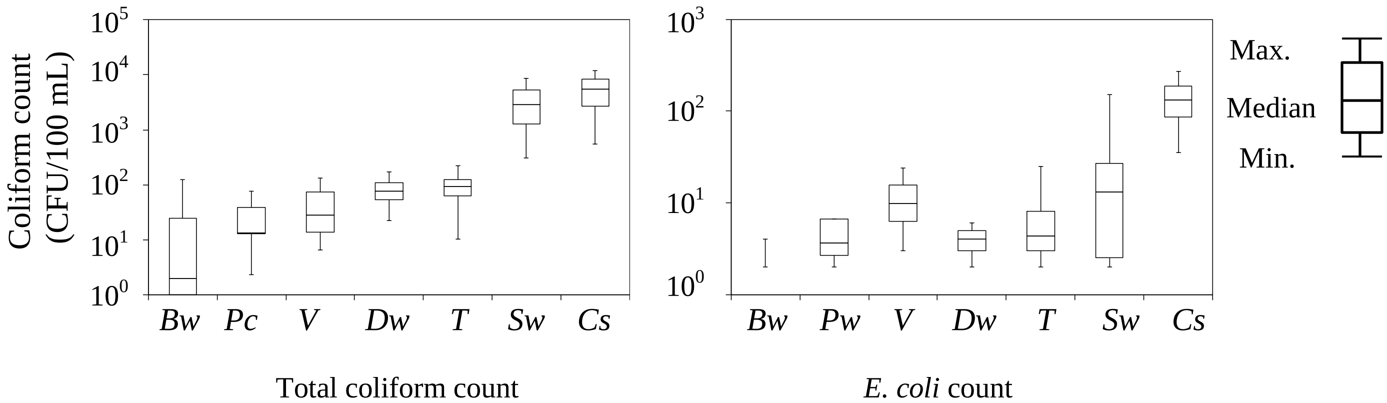


Figure 5.6 Coliform counts for different water supply sources

Note: *Bw*: Bottled water, *Pc:* Private pipe connection, *V*: Vendor, *Dw*: Deep well, *T*: Tanker, *Sw*: Shallow well, *Cs:* Community sources

The value 1 was added to *E. coli* count of bottled water.

5.3.4. Method of water storage and treatment

Households were found to use different home water treatment methods for drinking purposes as shown in **Table 5.2**. The higher proportion of households was found to use candle filter, followed by boiling and candle filter for treatment of water for drinking purpose. Households using bottled water for drinking purposes did not use any household water treatment methods. Since, microbial contamination was detected in bottled water as well, treatment of bottled water before consumption was essential.

Table 5.2 Type of household water treatment systems (*n* = 79)

Water treatment system	Respondents (%)
Only candle filter	29.2
Boil and candle filter	25.5
No treatment	23.6
Only boil	8.5
Reverse osmosis	9.4
Only SODIS	2.8

5.3.5. Water quality at different point of uses

Figure 5.7 shows *E. coli* count in different point of uses at households. The microbial water quality was found to change at various points of uses. The observed differences between samples from sources and household water containers reflect that number of indicator organisms increased during storage at home; however, for 13% of the samples, there was reduction of indicator organisms in containers than sources. The contamination was higher in storage container for non-potable purposes than for potable purposes. The storage tanks for non-potable purposes were placed outside the room or house and often close to toilet, while potable storage tank were placed inside the kitchen. These finding matched with previous studies which have reported that water samples collected from water storage tanks were more contaminated than the sample collected from the sources (Wright *et al*. 2004).

Households' water treatment system was found to effective, since the number of indicator organisms in samples collected after water treatment was statistically different from

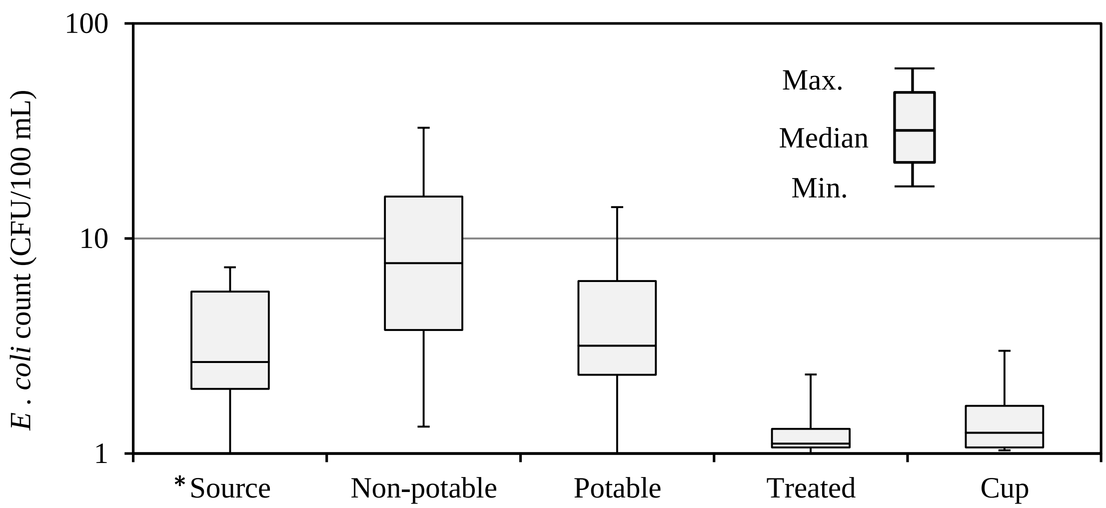


Figure 5.7 Comparison of coliform counts at different point of uses for households without overhead tank

Note: *Source refers to only private pipe connection and vendor.
The value 1 was added to remove 0 values.

samples collected from potable water tank at significant level (p > 0.01, Paired t-test). The number of *E. coli* in treated water was lower than those collected from sources or storage tank. All the sampled households collected water from household treatment system into pet bottle or cups for drinking purpose. The number of *E. coli* was found to increase in all samples collected from pet bottle and cup. Despite treatment of water, recontamination during the process of consumption increased health risks.

Containers with large mouthed had a significantly higher number of indicator organisms than compared to narrow mouthed containers as shown in **Fig. 5.8**. Narrow mouthed containers were mostly made up of steel, while large mouthed containers were plastic containers. Momba and Notshe (2003) also reported persistence of indicator organisms in polyethylene containers for longer than in galvanized steel containers.

Figure 5.8 shows that *E. coli* concentration for portable storage tank was found to increase, while its concentration was found to decrease in overhead tank. The difference in *E. coli*

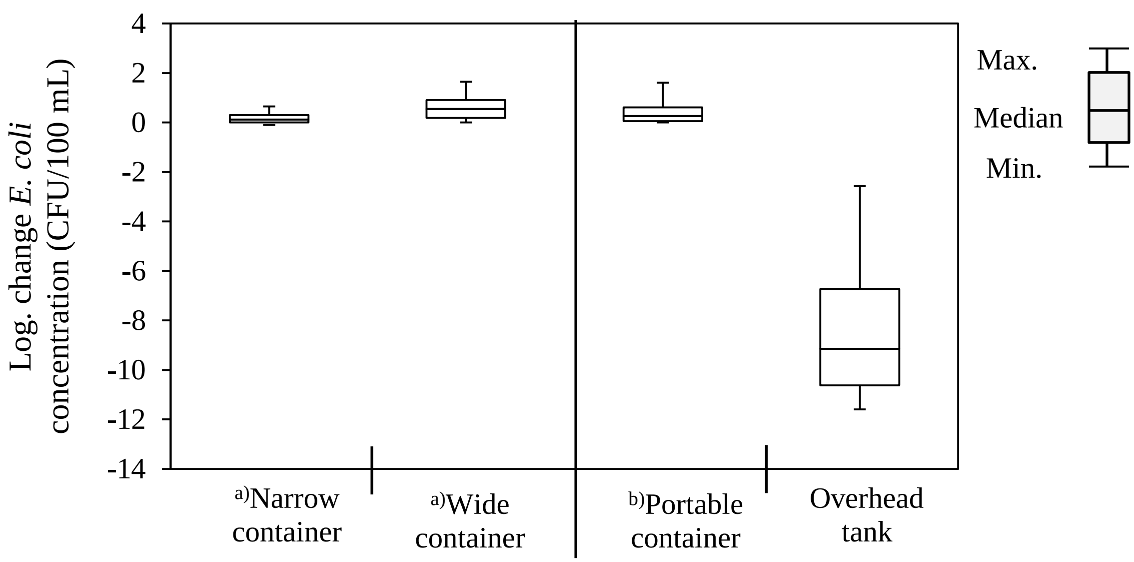


Figure 5.8 Comparison of coliform counts for different types of containers and water use pattern

Note: a) Portable containers
b) Both narrow and wide containers were pooled together.

concentration between portable container and overhead tank was statistically different at significant level ($p > 0.001$, Independent t-test). Therefore, households following consumption pattern as shown in **Figure 5.1 (A)** were at higher health risk than those following consumption pattern as shown in **Figure 5.1 (B)**. The possible reason for higher contamination in portable storage tank could be due to dipping of cups or jugs into the portable tank, while water from overhead tank was distributed through plumbing facility. In this study, concentration of *E. coli* in hands of household members was not examined. Trevett *et al*., (2005) reported that contamination of stored was possibly due to dipping of hands into the storage container.

5.3.6. Exposure analysis

Figure 5.9 shows distribution of amount of water swallowed during teeth brushing and mouth rinsing and it was found to be log-normally distributed, which was verified by Anderson Darling test. The average amount of water swallowed was 0.9 ± 0.4 mL/time. In an average, respondents were found to rinse their mouth 4 times per day. Hence, total amount of water swallowed per day was estimated as 3.6 mL/day.

Table 5.3 shows the calculation of annual exposure to *E. coli* for households having only

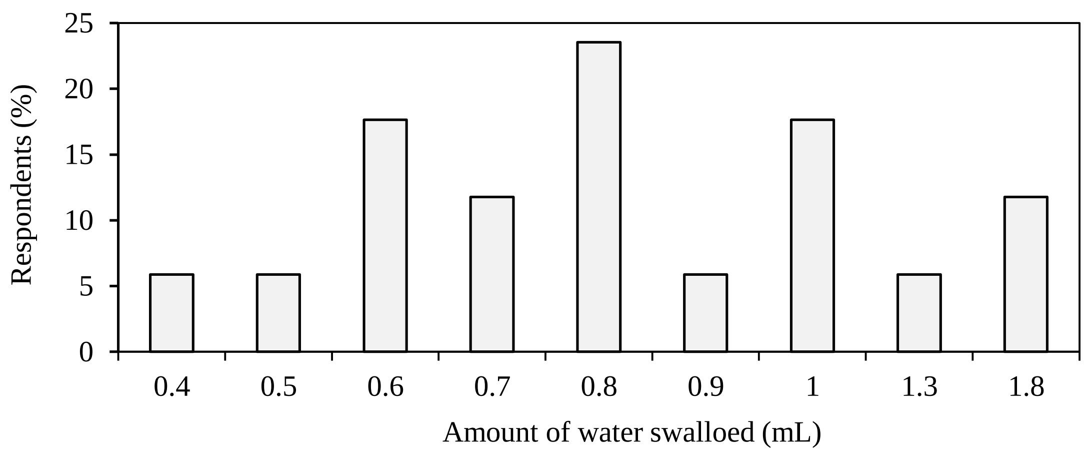


Figure 5.9 Distribution of amount of water swallowed during teeth brushing and mouth rinsing

three types of water consumption pattern *viz.* (1) community source for both potable and non-potable use, (2) bottled water for drinking and stored private pipe connection water (portable storage container) for other purposes and (3) bottled water for drinking and direct private pipe connection for other purposes. Since, *E. coli* was detected only in 2 samples of bottled water, maximum value was considered for the calculation.

Households using stone spouts consumed 3.2E+08 (CFU/year). The annual intake of *E. coli* was 2.5E+06 (CFU/year) for bottled water and stored piped water users; while it was 2.3E+06 (CFU/year) for bottled water and direct piped water users. Thus, by avoiding storage the exposure to fecal bacteria can be reduced by 2.0+05 (CFU/year). By improving storage conditions and treatment of water before consumption can significantly reduce exposure of households to microbial contamination and thus minimize health risks.

Table 5.3 Exposure analysis for consumption patterns

Consumption patterns	Purpose	Source	Amount of consumption (mL)	Parameters and its value (CFU/mL)	Type of distribution	Total Exposure (CFU/year)
Type 1	*Wd*	*Cs*	1680.6	μ=1.4; σ = 0.8	*N*	3.2E+08
	Ws	*Cs*	26.5	μ=2.8; σ =1.6	*Lnd*	
	Wt	*Cs*	3.6	μ=2.8; σ =1.6	*Lnd*	
Type 2	*Wd*	*Bw*	1680.6	0.01	-	2.5E+06
	Ws	*Pcs*	26.5	μ=0.07; σ = 0.04	*Ld*	
	Wt	*Pcs*	3.6	μ=0.07; σ = 0.04	*Ld*	
Type 3	*Wd*	*Bw*	1680.6	0.01	-	2.3E+06
	Ws	*Pcd*	26.5	μ= 0.02; σ = 0.04	*Ld*	
	Wt	*Pcd*	3.6	μ= 0.02; σ = 0.04	*Ld*	

Note: W*d*: Drinking; *Ws*: Shower; *Wt*: teeth brushing and mouth rinsing; *Bw*: Bottled water; *Pcs*: Private pipe connection stored; *Pcd*: Private pipe connection direct; *Cs*: Community sources; *N*: Normal distribution; *Lnd*: Lognormal distribution, *Ld*: Logistic distribution

5.4. Summary

Total coliform and *E. coli* were not detected at the outlet of water treatment plant but detected in tap of piped water, which shows contamination during water distribution. Total coliform and *E. coli* counts for samples collected from bottled water, piped water and vendor and tanker were significantly lower ($p < 0.05$) than wells and stone spouts. Though bottled water was perceived as good quality water, coliform were detected.

Microbial contamination was detected during storage, since *E. coli* counts for samples collected from storage containers were significantly higher ($p < 0.05$) than at supply points. Though water quality improved after treatment, however, post treatment contamination deteriorated quality of treated water. Water contamination was higher in non-potable containers than in potable containers. Also, water contamination in wide mouthed container was higher than in narrow mouthed container. Households using portable container were found to be exposed to higher health risk than those using overhead storage tank, as portable containers dipped jars or cup to withdraw water from tank.

Microbial exposure of households using portable containers for water storage was higher than those using overhead tank. The annual intake of *E. coli* for stone spouts users was 3.2E+08 (CFU), while it was 2.3E+06 (CFU) for bottled water and direct private pipe connection users.

Chapter 6

Potential water management measures at household level

6.1. Introduction

Water scarcity has been a growing problem in many cities of the world (Zhang and Brown, 2005; Zerah, 2009). Until recent years, large scale water supply projects have been thought as an only option to meet water demands (Gleick, 2003). An alternative water management approach to reduce water scarcity can be utilization of rainwater and gray water (Abdulla and Al-Shareef, 2009; Opare, 2012).

Earlier studies in Kathmandu have focused on piped water supply improvement and ground water management. Though the government emphasizes for alternative water management measures such as rainwater harvesting, decentralized water supply system to increase water availability but no study had been undertaken to identify and measure the effectiveness of those measures at household level. Lack of empirical data is one of the hurdles for exploration and implementation of water management measures at the household level.

As discussed in chapter 3 and 4, households have been depending on multiple water supply sources to cope with intermittent piped water supply and water consumption pattern of households was lower than minimum required value. Therefore, there is need of water management measures to improve water availability; however those measures may not be feasible for different socio-economic groups. Moreover, a study focused on users' attitudes and aspirations are needed in order to improve and scale up effective management measures. Therefore the specific objectives of this chapter are as follows:

a. To understand water management practices undertaken by households to cope with water shortage

b. To understand preferences of water supply management measures among different socio-economic group and water supply source users
c. To examine suitability of gray water reuse and rainwater harvesting for different socio-economic groups

6.2. Materials and Methods

6.2.1. Household interview survey

Multistage stratified random sampling was conducted for selection of 217 households. A structured questionnaire survey was conducted during December, 2011 and January, 2012. The estimation of total water consumption was based on questionnaire survey as shown in **Table 6.1** (see **Appendix I** for detailed information).

6.2.2. Key informants survey

Information on awareness program and costs for rainwater harvesting system, gray water treatment system and other demand management measures were collected from officials from governmental and non-governmental organizations, local entrepreneurs.

Table 6.1 Contents of the questionnaire

Theme	Type of question	Reference
1) Socio-economic information	Housing ownership	Table 6.2
	Monthly income, family size, plot size area, occupant	Table 6.3
	Roof area	Figure 6.3, 6.4
2) Water use facilities	Size of storage tank	Figure 6.4, 6.5
	Water efficient retrofits	Table 6.2, 6.3
3) Coping measures	Preferences and reasons for adopting coping measures	Table 6.4, 6.6
	Perception on rainwater and gray water use	Table 6.9

6.2.3. Data analysis

Chi-square test was used to examine the association between two dichotomous variables. Mann Whitney *U* test (Eq. 4.3) was used to examine difference between user and non-users of coping measures for interval data. The data were analyzed using PASW Statistics 18.

The respondents were asked to rank six different coping measures. The preference index score for each score was calculated as shown in Eq. 6.1.

$$P_m = \frac{\sum_{j=1}^{6} R_j * C_{iRm}}{N_i} \quad \text{(Eq. 6.1)}$$

where, P_m: Preference index score for a measure *m*

R: Score for rank *j* (1 least preferred and 6 most preferred)

C_{mR}: Number of households belonging to an income group *i*, ranking *R* for measure *m*

N_i: Sample size for an income group *i*

6.2.4. Potential calculation of coping measures

The potential of gray water and rainwater harvesting to improve water consumption of households were estimated using Eq. 6.2 to 6.9.

a) Gray water use potential

The amount of wastewater from hygiene, bathing and laundry reused for laundry and toilet use was estimated. The gray water use potential was calculated as follows:

$$Gwp = [H*(Th+Lh)] + [B*(Tb+Lb)] + [L*Tl] \quad (6.2)$$

where *Gwp* is gray-water-use potential (L/cap/day); *H*, *B* and *L* stands for amount of water consumed (L/cap/day) for hygiene, bathing and laundry, respectively; *Th*, *Tb* and *Tl* stands for ratio of reused water (-) for toilet use from hygiene, bathing and laundry, respectively;

Lh and Lb stands for ratio of reused water (-) for laundry from hygiene and bathing, respectively.

The values of H, B, and L were obtained in this study, while those of Th, Tb, Tl, Lh and Lb were calculated to maximize Gwp. Since there are no clear information of water quality differences of used water between hygiene and bathing, was assumed, *i.e.* $Th = Tb$ and $Lh = Lb$. Finally, ratios were estimated as follows:

$$Tl = 1 \tag{6.3}$$

$$Th = Tb = (Dt - L) / (H+B) \tag{6.4}$$

if $L > [(1 - Th)*H] + [(1 - Tb)*B]$

$$Lh = 1 - Th \tag{6.5}$$

$$Lb = 1 - Tb \tag{6.6}$$

if $L < [(1 - Th)*H] + [(1 - Tb)*B]$

$$Lh = Lb = L / [(1 - Th)*H] + [(1 - Tb)*B] \tag{6.7}$$

$$Sh = 1 - Th - Lh \tag{6.8}$$

$$Sb = 1 - Tb - Lb \tag{6.9}$$

where Dt stands for water demand for toilet (10.0 L/cap/day)[20)]; Sh and Sb stands for ratio of surplus gray water (-) from hygiene and bathing, which can be used for non-essential purposes such as plant watering and car washing.

b) Rainwater harvesting potential

Rainwater-harvesting potential was calculated as follows[18)]:

$$Rhp = Rf * A * R \tag{6.10}$$

where Rhp, rainwater-harvesting potential (L/month); Rf, rainfall (mm/month); A, area of the rooftop of a house (m^2); and R, runoff coefficient for the roof (-).

An average rooftop area of 95 m^2 and a run-off coefficient of 0.5 for flat roof were used in Eq. (6.10). The water supply potential (*Wsp*) of rainwater harvesting was calculated as follows:

if $W_{m\text{-}1} + Q_m - D \leq S$

$$Wsp_m = W_{m\text{-}1} + Q_m \tag{6.11}$$

$$W_\mathrm{m} = W_{m\text{-}1} + Q_m - D \tag{6.12}$$

if $W_{m\text{-}1} + Qm - D > S$

$$Wsp_m = S \tag{6.13}$$

$$W_m = S \tag{6.14}$$

where W_m, amount of water in the storage tank on the last day of month *m* (L); Q_m, rainwater harvesting potential in month *m* (L/month); *D*, monthly water demand (L/month); *S*, size of the storage tank (L); and Wsp_m, water supply potential for month *m* (L/month)

6.3.4. Assumptions

In this study, potential of raising existing water consumption by 35.0 L/cap/day for sanitation and bathing (Gleick, 1996) using gray water and rainwater was explored. Hence, additional water demand of 4200 L/month was assumed for a household an average size of 4 persons.

6.3. Results and Conclusion

6.3.1. Existing coping measures

Households were asked for months during which they experienced water scarcity for potable and non-potable purposes. The majority of households reported water shortages during months of March to June for both potable and non-potable purposes as shown in **Fig. 6.1**. Due to increase in rainfall in July, there was sharp decline in households reporting water shortages. During July to November higher number of households reported water shortage for potable use than non-potable use. It was reported that during July and August

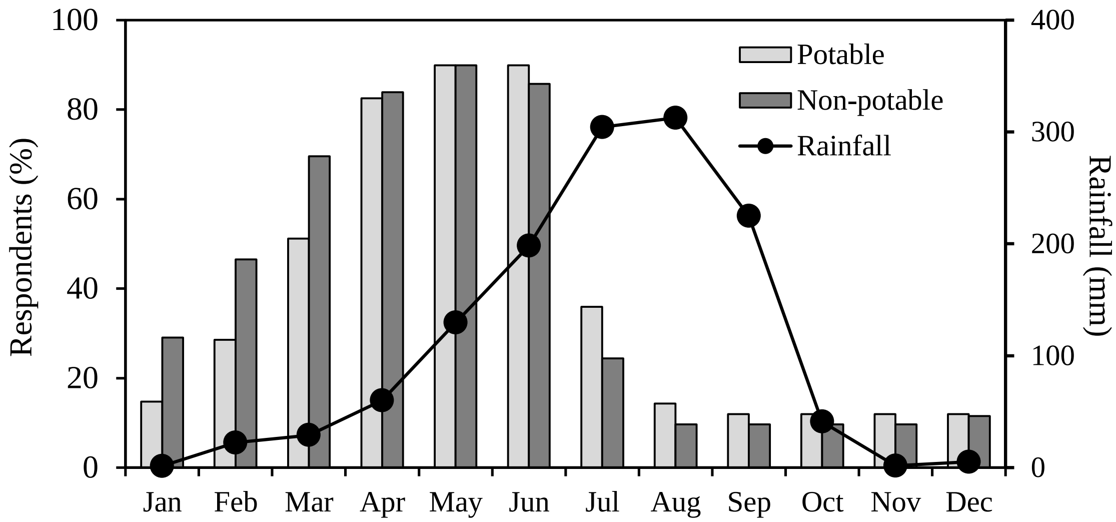


Figure 6.1 Water shortages during different months for potable and non-potable purposes

(monsoon) season, piped water quality was poor, hence households faced water shortage problem. Water management measures should provide adequate water during these months of water scarcity.

Households were found to adopt multiple measures to cope with water scarcity as listed in **Table 6.2**; however their adoption varied between house owner and renter. The uses of multiple water supply sources and storage of water were widely adopted by both owners and renters. Higher proportion of households receiving piped water supply more frequently were found to use fewer number of alternative water supply sources than those receiving less frequently as shown in **Fig. 6.2**. Though, water storage was adopted by owners and renters, their size of water storage tank varied significantly as renters lacked sufficient space for large storage tanks. Though the size of plot area was expected to influence size of storage tank of owners, there was no significant relation between them.

Rainwater harvesting practice was adopted by significantly higher number of owners than renters. The possible reason could be lack of space to store rainwater among renters.

Table 6.2 Coping measures adopted by households (%)

Coping measures	Description	Owners (n = 106)	Renters (n = 111)	p value
1. Multiple water supply	Use more than one water supply source	73.5	81.9	0.196
2. Large water-storage tank	Total size of water-storage tank > 0.5 m^3	79.2	18.0	0.000
3. Purchasing water	Purchase water from commercial supply sources *i.e.* bottled water, tanker or vendor	51.0	58.5	0.161
4. Rainwater harvesting	Collect and use rain water as water supply	51.9	30.6	0.001
5. Gray water use	Use gray water as water supply	43.3	38.6	0.203
6. Water consumption reduction	Reduce frequency of baths and laundry	41.5	61.2	0.003
7. Ground water extraction	Use groundwater as water supply	30.2	48.6	0.227
8. Water-efficient retrofit	Installation of water-efficient shower heads, dual flush toilet	4.7	0.0	0.026

Note: Statistically significant differences were examined between owners and renters using Chi-square test

Moreover, renters have been reported to be reluctant for investing on rainwater harvesting due to uncertainty over tenure (Opare, 2012). The number of renters reducing their water consumption to cope with water shortage was significantly higher than owners. This infers that water shortage is more serious among renters than owners. Since, owners possessed larger water storage tanks and had control over water facilities, which might have averted need of reducing water consumption.

Zerah (2000) found that socio-economic characteristics of adopters and non-adopters of a coping measure varied and thus concluded that any management measures designed without accounting socio-economic characteristics of households may not be successful.

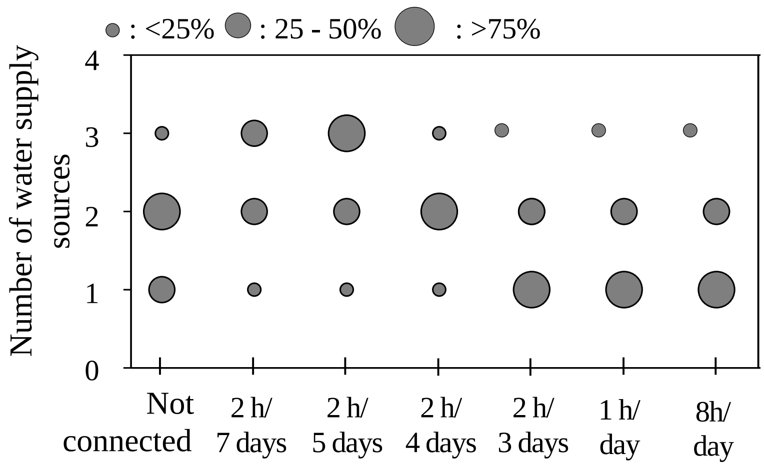


Figure 6.2 Number of water sources in varying piped water supply conditions (size of circles indicate proportion of respondents)

Therefore, the influence of socio-economic factors on adoption of 6 different coping measures was examined, as shown in **Table 6.3**. Monthly income of households that purchase water, collect rainwater and install water efficient retrofit was significantly higher than non- adopting households; however it was insignificant among gray water users and non-users. Since, purchasing water and installing water efficient retrofit were expensive measures, it was obvious that households with higher income could afford for them.

Plot size of households adopting for purchasing water was significantly lower than non-adopting households, while those adopting ground water extractions had significantly larger plot size than non-adopting households. As discussed in chapter 3, plot size was a determining factor for digging wells; hence households with larger plot size area were less dependent on water purchasing. Moreover, number of water supply sources used by households using private well was found to be significantly lower ($p < 0.001$) than private well non-users.

Education of household head was found to be significant for households opting to purchase water, reduce water consumption, groundwater extraction and water efficient retrofit. The

Table 6.3 Factors influencing selection of coping measures (median value)

Socioeconomic variables	Coping measures																	
	3. Purchasing water			4. Rainwater harvesting			5. Gray water use			6. Water consumption reduction			7. Ground water extraction			8. Water efficient retrofit		
	U	*Nu*	Sig.	*U*	*Nu*	Sig.	*U*	*Nu*	Sig.	*U*	*Nu*	Sig.	*U*	*Nu*	Sig.	*U*	*Nu*	Sig.
Monthly income (NRs in thousands)	24.0	10.0	***	20.0	12.0	**	16.0	18.0	-	15.0	20.0	***	22.0	16.0	***	32.0	24.0	***
[a] Plot size (m^2)	95.0	127.0	**	111.0	122.0	-	112.0	110.0	-	95.0	127.0	**	143.0	95.0	***	110.0	110.0	-
Education (years)	14.0	10.0	***	12.0	12.0	-	11.0	12.0	-	11.0	12.0	*	15.0	11.0	***	15.0	11.0	**
Family size (cap/household)	4.0	5.0	-	5.0	4.0	*	4.0	4.0	-	5.0	4.0	-	5.0	5.0	-	5.0	5.0	-
Occupant (cap/house)	10.0	8.0	**	8.0	8.0	-	8.0	9.0	-	8.0	8.0	-	10.0	8.0	**	8.0	8.0	-

Note: *U*: users, *Nu*: non-users, Sig.: result of statistical test (Mann-Whitney *U* test) of difference between *U* and *Nu* (***: $p < 0.001$), (**: $p < 0.01$), (*: $p < 0.05$), (- : not significant)
[a] For renters, plot size of their house owners was used for the analysis.

households opting to purchase water and groundwater extraction had significantly higher number of occupants than non-users. Family size of households was insignificant between adopters and non-adopters of all coping measures.

Since monthly income of households were found to influence selection of coping measures, we categorized households into three groups based on their monthly income i.e. low income (< NRs 150,001), middle income (NRs 15,001-30,000) and high income (> NRs 30,000).

The respondents were asked to rank six selected coping measures, based on their preferences, from 1 to 6 (6 for most preferred) and reasons for their preferences. **Table 6.4** shows preference score for different measures across income groups. Ground water extraction was the most preferred measures for both low and medium income group. Free, ease to access and no need of large storage tanks to store water were major reasons for high preference of groundwater over other coping measures. However, they also acknowledged high costs for construction of wells. Unlike those income groups, high income groups were found to prefer rainwater harvesting than groundwater extraction. Since, the majority of high income groups (53.6%, *n* = 41) were private well users and among them 36.3% (*n* = 22) were found to use tanker due to insufficient water in dry seasons. Hence they opine rainwater harvesting could be better than solely relying on groundwater.

Water consumption reduction was the second preferred option by low income; in contrast it was the least preferred option for high income group. Low and medium income households were found to cope by reducing their consumption for bathing purpose but alternatively consume more for cooking and hygiene purposes (face and hand washing *etc.*) as shown in **Table 6.5**. However their proportion of consumption for toilet use was similar to high income groups. The use of gray water and rainwater can reduce consumption of potable

Table 6.4 Preference ranking score for coping measures across income groups

Income group	Groundwater extraction	Water consumption reduction	Rainwater harvesting	Purchasing water	Gray water use	Water efficient retrofit
Low	4.7	4.2	4.0	4.0	2.9	1.2
Medium	5.1	4.0	4.3	3.9	2.2	1.5
High	4.9	2.5	5.3	4.2	2.3	1.6

Note: Higher values refer to higher preference

Table 6.5 Proportion of water consumption for various purposes (L/cap/day)

Purpose	Income group		
	Low	Medium	High
Drinking	1.3 (5.8)	1.6 (4.6)	2.2 (4.1)
Cooking	3.0 (13.6)	4.7 (13.2)	6.5 (12.3)
Laundry	3.2 (14.6)	5.8 (16.3)	7.9 (15.0)
Hygiene	3.6 (16.3)	5.2 (14.6)	6.7 (12.7)
Dishwashing	4.1 (18.6)	7.1 (20.2)	9.1 (17.2)
Toilet	4.1 (18.6)	6.0 (17.1)	9.7 (18.4)
Bathing	2.8 (12.5)	4.9 (14.0)	10.7 (20.3)

Note: The values in parentheses show percentage of water consumption for different purposes water for toilet flushing (Surendran and Wheatley, 1998; Lazarova, 2003). High income group had higher preference for purchasing water than low and medium income groups.

Due to high costs of other options, low income households might have chosen to reduce water consumption to cope with water scarcity. Zerah (2000) also reported that low income households tend to prefer for cheaper alternatives unlike higher income households. Such differences in preference among different socio-economic groups have to be considered for designing coping measures as households' level.

Table 6.6 shows reasons for high preference of selected measures. High and moderate preference score of rainwater for high and low and medium income groups reflects higher acceptance of rainwater harvesting to general public. Good quality and free availability of rainwater were major reasons for higher preference of rainwater. Also, declining groundwater level was reported as a reason for preferring rainwater. Gray water use and water efficient retrofitting were the least preferred measures for all income groups.

Though, people in Kathmandu are adopting various coping measures but they still lack water to meet the necessary water consumption target recommended by Gleick (50.0 L/cap/day). To meet this minimum target consumption, 6.0 m^3/month/household is required with an average family size of 4 persons. Water consumption survey revealed that in an average 18.0 L/cap/day of piped water supply was available. Thus, 32.0 L/cap/day of water is needed to achieve the minimum requirement.

Table 6.6 Reasons for high preference of selected measures (%)

Reasons	Groundwater extraction (n = 141)	Rainwater harvesting (n = 71)	Gray water use (n = 68)
Cheap	85.8	100.0	100.0
Convenient to use	100.0	66.2	100.0
Good quality	60.2	81.7	0
Declining groundwater	0	14.1	0

In this section, the potential of two following coping measures were examined. Firstly, the potential of gray water was examined since every household produce a certain amount of gray water and, therefore, its applicable coping measures for any households.

6.3.2. Potential of gray water use

Every household produces a certain amount of gray water, and therefore, gray water use is a applicable coping measure to any household. **Table 6.7** shows existing use of gray water for different purposes. As shown in the table, totally 31.3% of the households in Kathmandu used gray water generated from laundry, bathing, hygiene and dishwashing and higher proportion of them use it for toilet use.

Gwp (L/cap/day) was calculated based on Eq. (6.3) to (6.10). The calculation was conducted for three different income groups, using values of *H*, *B* and *L* as shown in **Table 6.8**. Pour flush toilet was used by 82.0% (n = 217) of respondents; Gleick (1996) reported that 10.0 L/cap/day of water was required for pour flush toilet. Therefore, *Dt* (water demand for toilet) was set as 10.0 L/cap/day. Unless surplus water was born, plant watering was excluded from *Gwp* estimation because is it not a basic water requirement. Water loss during collection of gray water was not considered.

Table 6.7 Proportion of gray water users for different purposes (n = 68)

Sources	Purposes (%)			
	For toilet	For plant watering	For laundry	No uses
Laundry	19.4	17.5	0	79.1
Bathing	18.4	6.5	7.8	67.3
Hygiene	17.1	5.1	5.5	72.3
Dishwashing	8.3	8.8	0	82.9

Table 6.8 Calculation of gray water use potential

Gw source	*Gw* production (L/cap/day)	Ratio of use (-)			*Gwp* (L/cap/day)		
		Rt	*Rl*	*Sh*	*Tu*	*Lu*	*Su*
Hygiene (*H*)		*Th*	*Lh*	*Sh*			
High *IG*	6.6	0.12	0.52	0.35	0.8	3.5	2.4
Medium *IG*	5.1	0.43	0.57	0.0	2.2	2.9	0.0
Low *IG*	4.7	0.69	0.31	0.0	3.3	1.5	0.0
Bathing (*B*)		*Tb*	*Lb*	*Sb*			
High *IG*	10.6	0.12	0.52	0.35	1.3	5.5	3.7
Medium *IG*	4.8	0.43	0.57	0.0	2.0	2.7	0.0
Low *IG*	3.6	0.69	0.31	0.0	2.5	1.1	0.0
Laundry (*L*)		*Tl*					
High *IG*	7.9	1.0	-	-	7.9	-	-
Medium *IG*	5.8	1.0	-	-	5.8	-	-
Low *IG*	4.2	1.0	-	-	4.2	-	-
Total							
High *IG*	25.1	-	-	-	10.0	9.0	6.1
Medium *IG*	15.6	-	-	-	10.0	5.6	0.0
Low *IG*	12.6	-	-	-	10.0	2.6	0.0

Note: *Gw*: gray water, *Rt*: ratio of use for toilet, *Rl*: ratio of use for laundry, *Rs*: ratio of surplus, *Tu*: use potential for toilet, *Lu*: use potential for laundry, *Su*: surplus *Gw*, *IG*: income group, *Th*, *Tb*, *Lh*, *Lb*, *Sh* and *Sb* are as defined in Eq. (6.2) to (6.9)

The results of the calculation were shown in **Table 6.8**. The total gray water production was 12.6, 15.6, and 25.1 L/cap/day for low, medium and high income groups, respectively. The gray water use would meet the amount of water required for toilet flushing across all groups and would save clean water for other purposes. Only high income group would have surplus amount of gray water and it can be used for plant watering or other purposes. Moreover, gray water use would increase water availability and meet the target amount (50.0 L/cap/day) by 69.6% for the low-income groups, while exceeding the target for the medium- and high-income groups. Thus, gray water will play a substantial role in increasing the availability of water.

6.3.3. Potential of rainwater harvesting

At the time of the survey, rooftop rainwater was harvested by 1.8% of the households for both potable and non-potable purposes and by 32.7% of the respondents for non-potable purposes only. In addition, 1.4% of respondents used rainwater to recharge their wells.

Figure 6.3 shows the rainwater harvesting potential (RWH) for a household with a rooftop area of 95 m^2. RWH exceeds 5 m^3 and reaches up to 15 m^3 in August; however due to limited water storage capacity of households, it is not possible to store as much as RWH. Therefore, the size of storage tank needed for fulfillment of water for whole year for an average family size of 4 persons was determined. The maximum water-storage tank sizes of the medium- and high-income groups (10,000 and 15,000 L, respectively) were considered for determining the tank size for storage of rainwater. In addition, the hit and trial method was used until the W_m (amount of water on the last day of the month, m) value was greater than the water demand throughout the year. The results indicated that, if the water demand (50.0 L/cap/day) is met by the piped water supply (18.0 L/cap/day) and rainwater harvesting throughout a year, the storage-tank capacity needed was 24,000 L (**Fig. 6.4 A**); however, if the amount of gray water produced by a medium-income household *i.e.*

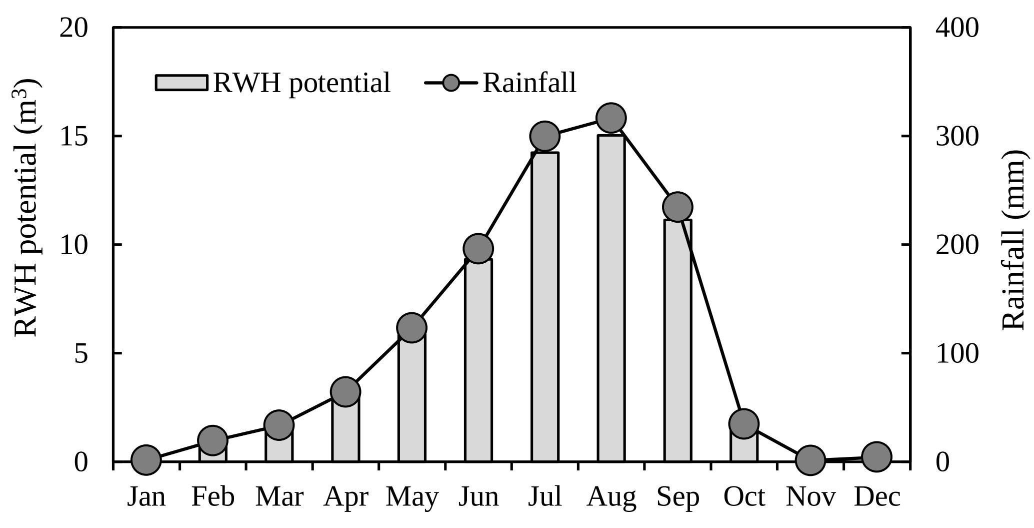


Figure 6.3 Rainwater harvesting potential for an average roof area (95 m^2)

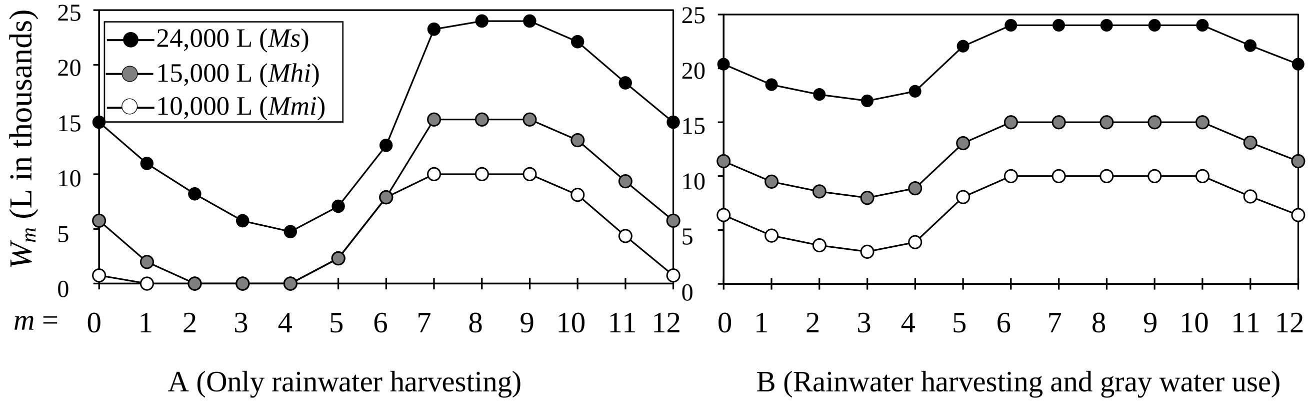


Fig. 6.4 Determination of tank size for water storage

Note: W_m: amount of water on the last day of the month (m) except W_0 (the last day of December in the previous year) *Ms*: maximum tank size, *Mhi*: maximum tank size of high-income group, *Mmi*: maximum tank size of medium-income group

15.6 L/cap/day was additionally available, a water-storage tank of 10,000 L was sufficient (**Fig. 6.4 B**).

A large storage capacity is needed to store sufficient water for the dry season. It was found that the average sizes of the tanks currently owned by the low-, middle-, and high-income

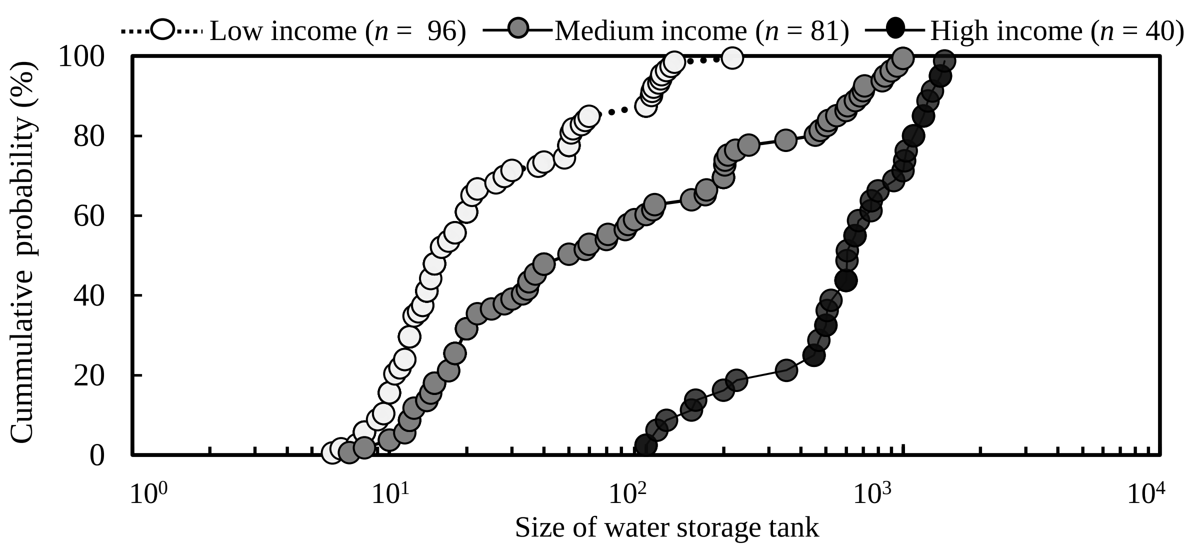


Figure 6.5 Distribution of water storage tank for different income groups

groups were 350, 2,500, and 8,000 L, respectively (**Fig. 6.5**). A combination of piped water, rainwater harvesting, and gray water use reduces the size of the required water-storage tank; however the existing tank sizes still need to be increased for all income groups. In particular, for the low-income and high-income groups and renters, it is infeasible to increase the size of the water-storage tank to meet the demand in the dry season.

The extent of rainwater harvesting can be increased by improving the runoff coefficient of the roof. A community based rainwater-harvesting system could be an alternative for low- and middle-income groups. Sharing of collected rainwater between owners and renters could also reduce water shortage problem, if not meet the recommended value. Also, use of gray water from cooking and dishwashing and treatment of gray water may also improve availability of water.

6.3.4. Barriers for gray water and rainwater harvesting

To understand barriers to gray water and rainwater harvesting, the households not adopting gray water use and/or rain water harvesting were asked about the reasons for not adopting those measures. Gray water use was considered socially unacceptable for 46.8% of the respondents and 28.4% of them believed it is unhygienic (**Table 6.9**). Thus, raising awareness and proper understanding of the risks of gray water use is essential for its acceptance.

Meanwhile, lack of space to store rain water and the unreliability of precipitation were reported as major difficulties for rainwater harvesting. The former reason may be particularly critical for the low-income group. Therefore, rain water harvesting may be a suitable measure for only the medium- and high-income groups. Unreliability of precipitation can be overcome by constructing a large water- storage tank.

6.3.5. Cost analysis of rainwater harvesting system

In this section, the costs of rainwater harvesting system was estimated based on information collected from agents (2 key informants) involved in installation of rainwater harvesting in Kathmandu valley. As shown in **Table 6.10**, rainwater harvesting will cost NRs 66,500

Table 6.9 Reasons for not using gray water and rainwater

Theme	Challenges	[a]Respondents (%) GW (*n* = 149)	RWH (*n* = 130)
Economic	High cost	18.9	11.1
Social	Culturally unacceptable	46.8	0.5
	Lack of knowledge	3.2	3.7
Technical	Unhygienic	28.5	12.9
	Lack of space to store water	25.3	45.2
	Lack of space for treatment	12.8	0
	Unreliable	0	38.2

Note: [a] Multiple choices
GW (Gray water use), RWH (Rainwater harvesting)

Table 6.10 Estimates for costs of rainwater harvesting system

S.N	**Equipements**	**Amount (NRs)**
1	First Flush	16,500.00
2	Bio Sand Filter	10,000.00
3	Iron Stand (Ht = 7ft)	9,000.00
4	1 HP Electric Water Pump With Pipe	10,000.00
5	Plumbing Charge	7,000.00
6	Transportation Charge For Materials	3,000.00
7	Pre-filter plant	11,000.00
8	Storage tank 10,000 L	160,000.00
Total cost without storage tank		66,500.00
Total costs with storage tank		226,500.00

Source: Key informant survey
Note: 1 USD = NRs 85.6

without including storage tank while including storage tank of size 10,000 L, it will rise to NRs 226,500. The storage tank was the most costly accessory of the system, since it contributed to 70.6% of total cost of installation of rainwater harvesting with water storage tank. The rainwater harvesting system installed by agents in Kathmandu valley includes a small tank for first flush and bio-sand filter for improving water quality. Only 4.2% of respondents using rainwater had installed rainwater harvesting. Therefore, majority of respondents did not use any water treatment system and simply collected rainwater from roof into a collection tank.

In this study, we calculated and compared repay duration of rainwater harvesting system for tanker users. As discussed earlier, rainwater system may be more suitable for large tank size owners than others. Since, tanker users possess large sized tank, the cost of storage tank can be assumed to be same in both cases. Operating cost and inflation has not been taken into account.

Table 6.11 shows comparison of cost between tanker and rainwater harvesting users. Households' annual water demand was estimated at 73,000 L. Based on existing charges of water tankers, it will cost NRs 1,500 for 5000 L. Therefore, annual expenses of households solely depending on tanker will incur expenses of NRs 21,900. The installation cost of rainwater harvesting without including storage tank water NRs 66,500, while including storage tank was NRs 226,500. Based on cost analysis for tanker, the total investment for rainwater harvesting without storage tank will be repaid back in 3 years, while it will take 10 years for repayment of rainwater harvesting with storage tank.

6.5. Summary

This paper investigated potential of gray water use and rainwater for bathing and sanitation services across different income groups. Water consumption of households in Kathmandu valley was found to be low compared other cities in the region. Also, water consumption of

Table 6.11 Comparison of cost between tanker and rainwater harvesting

Calculations	**Volume of water (L)**	**Costs (NRs)**
Annual water demand for a household (50 L X 4 persons X 3655 days)	73,000 L	
Cost of tanker for 5000 L	-	1,500
Annual expenses for buying water with tanker (Annual water demand/5000 L X NRs 1,500)	-	21,900
Cost of rainwater harvesting system without including expenses for storage tank	-	66,500
Cost of rainwater harvesting system including expenses for 10,000 L storage tank	-	226,500
Repaying period without including storage tank	3 years	
Repaying period with including storage tank	10 years	

Note: 1 USD = NRs 85.6

low income was significantly lower than higher income groups. Since, households were coping with water shortage by reducing their water consumption for non-potable purposes; additional water demand of 35.0 L/cap/day was proposed to meet minimum water requirement (50.0 L/cap/day).

The study considered only general hygiene, laundry and bath as sources of gray water. Using gray water generated from general hygiene, bathing and laundry, households can increase their water consumption. Due to size of water storage tank, rainwater harvesting was more feasible for medium and high income group than low income group. Only rainwater or rainwater and piped water supply cannot meet targeted water demand for both income groups. However, either increasing size of water tank or using gray water with rainwater and piped water targeted water demand will be met throughout a year.

Rainwater harvesting was more acceptable to respondents than gray water use. Households were found to be enthusiastic for rainwater harvesting due to increasing water shortage. Moreover, installation of rainwater harvesting was found to be cost-effective than purchasing water from tankers.

Although the potential of gray water use and rainwater harvesting was examined as coping measures, there are barriers to their use as the sole solutions to water scarcity at this time. Thus, the use of multiple water sources may be regarded as a reasonable mechanism for coping with water scarcity in the city. For improving water availability, gray water use from various activities and its treatment should be considered.

Chapter 7

Conclusions and Recommendations

7.1. Conclusions

Households in Kathmandu valley has been suffering from water shortage. The piped water supply is intermittent and insufficient for households. Though the government has undertaken a project to increase and expand piped water supply and its coverage but has been delayed for years. In this context, households have been depending on groundwater but due to lack of proper management and monitoring, ground water extraction has exceeded it recharge rate.

In this context, this study aims to understand households' choices of water supply sources and their water consumption pattern in order to identify suitable water management measures for coping with water shortages at household level. Moreover, this study explores influence of socio-economic factors on water management. In order to gather information on water supply sources and their preferences for coping measures, household interview survey was done. Based on diary method, water consumption survey at household level was done to understand their water consumption pattern. Moreover, microbial water quality sampling of supply sources and at point of uses was done to identify pathways of microbial water contamination.

Household were found to use multiple water supply sources. The majority of households were dependent on private pipe connection followed by private well. Due to insufficient piped water supply and poor water quality, significant number of households was dependent on alternative water supply sources. During dry season, private pipe connection and private well users shifted to use tanker, vendor and bottled water due to decline in piped water supply and drying of groundwater.

Households were found to use different water supply sources for potable and non-potable purposes. Their perception on aesthetic water qualities i.e. taste, odor, color and turbidity influenced selection of the water supply sources for drinking purpose. Households perceived bottled water and public standpipe as good, while public well and private well as poor quality water supply sources.

The socio-economic factors of household were found to be associated with selection of water supply sources. Low income and households having low educated household head consumed community sources for potable use, while higher educated and high income used bottled water for drinking. Household having high monthly income used tanker for non-potable purposes.

Total average water consumption of households in Kathmandu valley was 32.3 L./cap/day, which was lower than minimum recommended value of 50 L/cap/day. The total amount of water consumption of households using tanker and private well was higher than other water supply sources users.

The amount of water consumed for daily household's activities was found to be lower than minimum required values. Low frequency of laundry and bath and adoption of water conservation measures can be attributed to low water consumption in Kathmandu in Kathmandu valley. Despite water shortage high proportion of water consumption was consumed for toilet flushing and dishwashing

Monthly income of households was positively correlated with water consumption and was found to be a major predictor of volume of water consumption. The use of bottled water and private well were positivity correlated with water consumption for potable and non-potable purposes, respectively.

Water contamination during piped water supply distribution was detected. Stone spouts and private well were the most contaminated water supply sources. Though bottled water was perceived as good quality water, coliform were detected. Microbial contamination was detected to increase during storage at household level. Water treatment at household level was effective for reducing microbial organisms; however post-treatment contamination was detected.

Households were found to use multiple coping measures in order to cope with water shortage. Households' having high monthly income were found to drill well and purchase water while those with low income coped by reducing their consumption for bathing and laundry, and instead, increased the consumption for more essential consumptions such as hygiene, cooking.

Gray water use was found to be feasible across different economic groups. Rainwater harvesting was more suitable for households with higher income, and larger storage tanks. In order to meet the minimum requirement (50/L/cap/day) throughout a year, the capacity of rain water storage tank needed to be more than 8000 L. Installation of rainwater harvesting was found to be cost-effective in long run rather than using tanker.

7.2. Recommendations

The results showed that socio-economic characteristics of households influenced selection of water supply sources, water consumption and water demand measures. On the basis of the findings following are the recommendations:

(1) In context of growing economy and lifestyles of households of Kathmandu valley, forecasting change of water consumption is recommended.

(2) For improving water availability, alternative water management measures like rainwater harvesting and gray water reuse should be promoted.

(3) The potential of groundwater recharging and community based rainwater harvesting system should be explored.

(4) The regular monitoring of quality of water supply sources and awareness raising measures for improving hygiene practices.

(5) The sharing of rainwater between house owners and renters can reduce the socio-economic barriers of rainwater harvesting.

(6) Further researches on rainwater quality should be conducted and the potential health risks from consumption of rainwater should be evaluated.

(7) The treatment of gray water at households and community level and its reuse should be further studied.

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Appendix I

Questionnaires for water consumption pattern

Name: ________________________________ Age: ______Gender: ______________

Education level: __________________ Occupation: ___________________________

Monthly Income: ______________________________

Address of respondent: ___________________**GPS location:** ____________________

Telephone number of respondent: ____

How long have you been living here? ______________________

Number of family members (living in house): _______________________

Details about family members:

	60 and above	15-60	Below 15
Male			
Female			

1. House area: ____________ Roof top area:_________ Garden area: __________
2. Storey: ________
3. Number of toilets/bathrooms: ________
4. Number of faucets (tap): ___________
5. **Information on other households in the building (if any)**

Number of members	Number of rooms	Age Groups		
		60 and above	15-60	Below 15
1:				
2:				
3:				
4:				
5:				

6. Usage of Water

Usages / **Sources**	In which months, which source of water do you use and for what purposes? Please rank sources on basis of preference for a purpose (1 for most preferred).								
	Drink	Cook	Bath	Hygiene	Laundry	Toilet	Dish wash	House cleaning	Vehicle wash	Garden
Piped (private)										
Piped (public)										
Dug wells (Private)										
Dug wells (Public)										
Tube wells (Private)										
Tube wells (Public)										
Tankers										
Vendors										
Stone spouts										
Springs										
Bottled water										
Rainwater										
Ponds										
Other sources (if any)										

7. Please provide your perception on water sources (Yes/No/don't know)

Sources	Are you satisfied with following parameters of water quality of sources? and please state reason if any	Are you satisfied with following parameters of water of sources? and please state reason, if any
	1. Turbidity: 2. Taste: 3. Color: 4. Smell:	1. Reliability 2. Price 3. Quantity 4. Safety
	1. Turbidity: 2. Taste: 3. Color: 4. Smell:	1. Reliability 2. Price 3. Quantity 4. Safety
	1. Turbidity: 2. Taste: 3. Color: 4. Smell:	1. Reliability 2. Price 3. Quantity 4. Safety

8. Please provide information on frequency and duration of water distribution of your sources for different months, if any?

Sources	Months	Frequency	Duration

9. Do you have any water sources (vendors, springs, wells, stone spouts, river, and pond) close to your house? If yes, please provide following information:

Sources	Distance of source	Time taken to fetch water	Perception on sources (Satisfied/ Unsatisfied/ Don't know)			
			Quality	Quantity	Price	Convenience

10. Changes of water sources (Please circle the options, if any)

Have you changed your sources in recent 5-10 years?		Reasons for change of sources	Have you noticed any changes in recent years in your source quality (smell, turbidity, taste, odor or *others*) and quantity
Sources used in the past	Recent sources		
		1. pollution of previous source 2. scarcity at previous source, 3. better quality of new source 4. convenience of new source 5. 24 hours supply of new source, 6.*others*	1. Worsening of quality 2. Improving quality 3. Increase of availability 4. Decrease of availability
		1. pollution of previous source 2. scarcity at previous source, 3. better quality of new source 4. convenience of new source 5. 24 hours supply of new source, 6.*others*	1. Worsening of quality 2. Improving quality 3. Increase of availability 4. Decrease of availability
		1. pollution of previous source 2. scarcity at previous source, 3. better quality of new source 4. convenience of new source 6.*others*	1. Worsening of quality 2. Improving quality 3. Increase of availability 4. Decrease of availability

11. Please provide information on water treatment methods , (if any)

Source	Purpose	Treatment method	Installation cost (if any)	Maintenance cost (if any)	Reason for selection of method (Please circle suitable options)
					1. Requirement 2. Cheap 3. Convenient 4. Others (if any)
					1. Requirement 2. Cheap 3. Convenient 4. Others (if any)

12. Information on storage of water

Type of storage tank (overhead, underground, portable)	Size (liters)	Numbers	Installation Costs	Maintenance costs (if any)	Material	Cleaning time interval

13. Expenses for water:

Sources	Monthly bills	Installation fee (year of installation)	Maintenance cost (if any)	Do you know tariff rates of water sources are high/normal/low?
Piped (private)				
Piped (public)				
Dug wells (Private)				
Dug wells (Public)				
Tube wells (Private)				
Tube wells (Public)				
Tankers		X	X	
Vendors		X	X	
Bottled water		X	X	
Ponds				
Springs				
Other (if any)				

14. Water use behavior

Question	Yes/No	Remarks (please explain)
i. How many liters of water or how many buckets of water do you fetch from tap/wells/stone spouts? Please state size of bucket.	X	Amount: Or, Size of bucket: Frequency:
If tanker is the source, how much of water do you buy from tankers and what is the time interval?	X	Amount: Frequency:
If bottled water is the source, how many bottled water jars do you buy and what is the time interval? Please state size of jar.	X	Size of jar: Frequency:
If direct pumping from wells, what is the capacity of your pumps, duration of pumping and how often do you refill it?	X	Amount: Or, Capacity of pump: Duration of pumping: Frequency of pumping:
ii. Is water supply enough to meet your needs? If no, how many liters do you think you need more for your family and for what purpose?		Purpose | Amount
iii. If ii is no, what are problems due to water scarcity? Please tick suitable options.		Stinking toilet ( ) Less sleeping hours ( ) Less water for cleaning house ( ) Less water for personal hygiene ( ) Waste of time ( ) Conflict with neighbors ( ) Others:
iv. Have you taken any measures to cope with water scarcity? If yes, please tick suitable options.		Collect and store rainwater for non-potable use ( ) Buy water from tankers or other sources ( ) Increase storage capacity of tanks ( ) Drill groundwater ( ) Water sharing with neighbors ( ) Bathing, laundry at stone spouts/springs/river ( ) Use public bathroom ( ) Lower water flow while using ( ) Repair leaks ( ) *Others:*
v. Does water consumption of your family change during any months in a year? **Please select reasons for increasing or decreasing** Festivals, low availability, high availability, months of load shedding, others		Month | Reasons: Decrease | Increase
vi. In an average, how many times a week does your family members take bath? Please tick on the practice of taking bath in your family.		Shower (use tap): Pour water from bucket: *Others:*

vii. How many times a week does your family wash clothes?		Months	Frequency	Type (manual/ machine)
viii. What type of toilet do you have?		Cistern flush toilet:		( )
		Pour flush toilet:		( )
		Dry toilets:		( )
		Rented (Public) toilets:		( )
		No toilets:		( )
		Others:		( )
ix. In an average, how much water do you pour after using toilets?		Short:		
		Long:		
x. In recent 5-10 years, has water consumption of your family increased or decreased? If yes, why?		Options		Decrease/ Increase
		Increase in number of members		
		Decrease in number of members		
		Increase of water consuming appliances		
		Decrease of water consuming appliances		
		Increase in number of water consuming activities		
		Decrease in number of water consuming activities		
		Increase water supply		
		Decrease water supply		
xi. Please rank your preference for adoption of any these measures to resolve water scarcity problems at household level. 1 for most preferred.		Options		Rank
		Increase size of storage tank		
		Groundwater pumping		
		Install water efficient retrofits		
		Gray water treatment system		
		Reduce water consumption		

15. Perception on rainwater

Question		Remarks (please explain)
i. Do you practice rain water harvesting? Please tick source of information on rainwater	Always ( ) Sometimes( ) Never ( )	Traditional practice ( ) Neighbor ( ) Media ( ) NGOs ( )

		Others ( )
ii. If 'i', yes, how long have been doing rain water harvesting?	X	Years: Before water scarcity ( ) After water scarcity ( )
iii. If 'i' yes, reasons for rainwater harvesting? (Please tick)		Scarcity of conventional water sources ( ) Good quality ( ) Freely available ( ) Traditionally practiced ( ) *Others*:
iv. If 'i' yes, how do you do rainwater collection? (Please tick)	X	Installation of system ( ) Without system ( ) *Others*:
v. If 'i' yes, how many months does rainwater lasts?		
vi. If 'i' yes, what is the capacity of your rainwater collection tank?		
vii. If 'i' yes, do you treat rainwater before using? If yes, please state about treatment method.		
viii. If 'i' yes, are there any problems for rainwater collection? (Please tick)	X	No space for storage tanks ( ) Dirty roof surface ( ) Poor quality of stored rainwater ( ) Don't know about rainwater harvesting ( ) Expensive to install and buy tanks ( ) *Others:* ( )
ix. If 'i' no, why you don't do rainwater collection? (Please tick) Remarks:	X	Surplus water: Inconvenient: Unaffordable cost to install system: Pose health risk: Not enough space for rainwater storage: Don't know about rainwater collection: No reason: *Others:*

16. Where do you dispose wastewater?

Sources of wastewater	Drainage of wastewater*
Kitchen	
Bathroom	
Laundry	
Toilet	
Others	

*Septic Tank- effluents into soil or drain pipe, Drain pipe, open ground, ponds

If septic tanks, how often do you clean your septic tank? ________________________

Is manpower easily available for cleaning septic tank? _________________________

What is charge for septic tank cleaning? ____________________________________

17. Perception on gray water reuse (Source of gray water: kitchen, bathing, washing, cleaning)

Question		Explanation		
i. Do you use gray water?	( ) Always ( ) Sometimes ( ) Never	Traditional practice ( ) Neighbor ( ) Media ( ) NGOs ( ) Others ( )		
ii. Why do you use gray water?		Scarcity of conventional water sources:		
		Relatively satisfactory quality for non-potable use:		
		Others:		
iii. If 'i' is yes, what are gray water sources and purposes of use?	X	Source	Use	Years of use
iv. If 'i' is yes, do you do any treatment before using?		If yes, what method?		
v. If 'i' is no, why you don't reuse gray water?		No need: ( )		
		Health risks: ( )		
		Smells bad: ( )		
		Inconvenient for collection of gray water: ( )		
		Don't know can be reused: ( )		
		Don't have culture of using it: ( )		
		Others: ( )		

18. Groundwater details (only if, respondents use ground water sources)

Question	Yes or No or Don't know	Explanation			
i. What measures have you undertaken for conservation and management of groundwater?		Groundwater recharge ( )			
		Cleaning and maintenance of wells ( )			
		Control groundwater abstraction ( )			
		Do nothing ( )			
		Others: ( )			
ii. Please provide following information on groundwater.		Depth	Year of drilling	Have you increased depth later, if yes, how much?	Do you think tariff should be charged for groundwwater? (yes/no/don't know)

iii. What are problems for conserving groundwater?		Lack of alternative source:
		Lack of resources:
		Lack of knowledge:
		Don’t know:
		Others:

19. Information on water user Committee

Question	Yes or No or Don’t know	Explanation		
i. In your community, do you have any kind of water supply management committee? If yes, what does it do?		Water supply distribution ( )		
		Water source conservation ( )		
		organize awareness raising programs ( )		
		file complaints at KUKL ( )		
		Others		
ii. If ‘i’ yes, are you satisfied with the activities of the committee? (Yes/No/No answer) and why?		Water supply has improved ( )		
		Water supply has not improved ( )		
		Transparency of financial accounts ( )		
		No transparency of financial accounts ( )		
		Biasness ( )		
		Fair distribution ( )		
		Others:		
iii. How often does committee call meetings?		Annual ( )		
		Monthly ( )		
		Others:		
iv. If ‘i’ yes, Do you attend meetings called by committee?		Regular	Sometimes	Never
v. How do you rate your participation in meetings?		Active	Neutral	Inactive

Appendix II

Questionnaires for microbial survey

Name: ____________________________________ Age: ______Gender: _______________

Monthly Income: ___________________________ Family size: ___________

Address of respondent: ____________________**GPS location:** _____________________

Telephone number of respondent: ____

1. Please provide information on usages of water supply sources

Sources	Purposes	
	Potable (drinking, cooking)	Non-potable (Hygiene, bathing, laundry, dishwashing *etc.*)
Private pipe connection		
Public standpipe		
Private wells		
Public wells		
Tanker		
Vendor		
Bottled water		
Others (if any)		

2. Please provide your perception on water sources (Yes/No/don't know)

Sources	Are you satisfied with following parameters of water quality of sources? Please state reasons if any.
	Turbidity ( ) Yes ( ) No Taste ( ) Yes ( ) No Color ( ) Yes ( ) No Smell ( ) Yes ( ) No
	Turbidity ( ) Yes ( ) No Taste ( ) Yes ( ) No Color ( ) Yes ( ) No Smell ( ) Yes ( ) No
	Turbidity ( ) Yes ( ) No Taste ( ) Yes ( ) No Color ( ) Yes ( ) No Smell ( ) Yes ( ) No

3. Information on storage of water

Type of storage tank (overhead, underground, portable)	Size (liters)	Location of storage tank	Purposes (potable, non-potable)	Material (steel, plastic, clay)	How many days before did you clean storage tank)

4. Do you cover your water storage tank? (Please tick)

( ) Yes ( ) No

5. Do you treat water? (Please tick)

( ) Yes ( ) No

6. If Q5 is yes, please provide information on water treatment methods.

Source	Purpose	Treatment method

Appendix III (A) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike Cleaning
1	Pc and Prw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Prw	Prw	Prw	Pc and Prw	Prw	0	Prw
2	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
3	Pc and Prw	Pc	Pc	Pc	Pc	Pc	Prw	0	Pc and Prw	Prw	Prw	Prw
4	Pc and Prw	Pc	Pc	Prw	Pc and Prw	Prw	Prw	Prw	Pc and Prw	0	0	0
5	Pc and Prw	Pc	Pc	Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Pc and Prw	0	Pc and Prw
6	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	0
7	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0
8	Prw	PrW	PrW	PrW	PrW	PrW	PrW	PrW	0	PrW	0	Prw
9	Pc, V and Bw	Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc	Pc
10	Pc, T and Bw	Bw	Pc	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	T
11	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
12	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
13	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
14	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
15	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
16	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
17	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc	Pc and Cw	Pc and Cw	Cw
18	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
19	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
20	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc	Pc and Cw	Pc and Cw	Cw
21	Pc and Prw	Pc	Pc and Prw	Pc	Pc	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Prw	Prw	Prw
22	Pc and Ss	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
23	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0
24	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc	0	0
25	Pc and V	Pc	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (B) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike Cleaning
26	Pc, V and Bw	Pc and Bw	Pc	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc	0	0
27	Pc and Prw	Pc	Pc	Pc	Pc	Pc	Pc and Prw	Pc and Prw	0	Prw	0	Prw
28	Pc, Prw and Bw	Pc and Bw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Prw	Prw	Prw
29	Pc, Prw and V	Pc	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	0	Prw	0	0
30	Pc, Prw and T	Pc and T	Pc and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Prw	Prw	Prw
31	Pc, T and Bw	Bw	Pc	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	T
32	Pc and Prw	Pc	Pc	Pc	Prw	Prw	Pc and Prw	Pc and Prw	0	Prw	Prw	0
33	Pc, Prw and Bw	Bw	Pc	Pc	Pc and Prw	Prw	Pc and Prw	Pc and Prw	0	Prw	0	Prw
34	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	0	0
35	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	Pc and V	0
36	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
37	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
38	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	0	0
39	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	0	0	0	0
40	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	0	0	0	0
41	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	0	0	0	0
42	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
43	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
44	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
45	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (C) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike Cleaning
46	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	0	0
47	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc
48	Pc, Prw and T	Pc	Pc and T	T	T	Prw and T	Prw and T	Prw and T	Pc, Prw and T	Prw	Prw	Prw
49	Pc, Prw and T	Pc	Pc and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Prw and T	0	0
50	Pc, Ss and Bw	Pc and Bw	Pc	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and	0	Pc	Ss	0
51	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
52	Pc, Prw and Bw	Bw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Prw	0	0
53	Pc, Ss and Bw	Pc and Bw	Pc	Pc	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	0	Pc and Ss	0	0
54	Pc and Ss	Pc	Pc	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	0	Pc	Ss	0
55	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
56	Pc and Prw	Pc	Pc	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Prw	0	Prw
57	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	0	0	0
58	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	0	0	0
59	Pc, Prw and Bw	Pc and Bw	Pc	Prw	Prw	Prw	Prw	Prw	0	Prw	0	Prw
60	Pc, V and Ss	Pc	Pc and V	Pc and V	Pc and V	Pc and V	Pc, V and SS	Pc and SS	Pc and SS	Pc and Ss	Ss	Ss
61	Pc, Prw and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Prw	Prw	0	Prw	0	0
62	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
63	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	0	T
64	Pc, Prw and V	Pc	Pc and V	Pc and V	Pc, Prw and V	Pc and V	Prw	Prw	0	Prw	0	0
65	Pc, Cw, Bw	Pc and Bw	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Cw	Cw	0	Cw	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (D) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
66	Pc, Cw, Bw	Pc and Bw	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc	Pc and Cw	Pc	0
67	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and	0	Cw	0	0
68	Pc, T and Bw	Bw	Pc	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
69	Prw and Bw	Prw and Bw	Prw	Prw	Prw	Prw	Prw	Prw	0	Prw	Prw	0
70	Prw, T and Bw	T and Bw	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	0	0
71	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	0	T
72	Pc and Prw	Pc	Pc	Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Pc and Prw	0	Pc and Prw
73	Pc, Prw and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and Prw	Prw	T	Prw and T	0	0
74	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0
75	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0
76	Ps and Prw	Ps	Ps	Prw	Prw	Prw	Prw	Prw	0	0	0	0
77	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
78	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
79	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
80	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc
81	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc
82	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	0	0
83	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0	0	0
84	Pc, Prw and T	Pc and T	Pc and T	Prw and T	Prw and T	Prw and T	Prw	Prw	Pc, Prw and T	Prw and T	0	Prw
85	Pc, V and Bw	Pc and Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc
86	Pc, V and Bw	Pc and Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	0
87	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0	0	0
88	Pc, Prw and Bw	Pc and Bw	Pc	Prw	Prw	Prw	Prw	Prw	0	Prw	Prw	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (E) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
66	Pc, Cw, Bw	Pc and Bw	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc	Pc and Cw	Pc	0
67	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and	0	Cw	0	0
68	Pc, T and Bw	Bw	Pc	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
69	Prw and Bw	Prw and Bw	Prw	Prw	Prw	Prw	Prw	Prw	0	Prw	Prw	0
70	Prw, T and Bw	T and Bw	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	0	0
71	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	0	T
72	Pc and Prw	Pc	Pc	Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Pc and Prw	0	Pc and Prw
73	Pc, Prw and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and Prw	Prw	T	Prw and T	0	0
74	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0
75	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0
76	Ps and Prw	Ps	Ps	Prw	Prw	Prw	Prw	Prw	0	0	0	0
77	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
78	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
79	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
80	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc
81	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc
82	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	0	0
83	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0	0	0
84	Pc, Prw and T	Pc and T	Pc and T	Prw and T	Prw and T	Prw and T	Prw	Prw	Pc, Prw and T	Prw and T	0	Prw
85	Pc, V and Bw	Pc and Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc
86	Pc, V and Bw	Pc and Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	0
87	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0	0	0
88	Pc, Prw and Bw	Pc and Bw	Pc	Prw	Prw	Prw	Prw	Prw	0	Prw	Prw	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (F) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
89	Pc, Prw and Bw	Pc and Bw	Pc	Prw	Prw	Prw	Prw	Prw	0	Prw	0	Prw
90	Prw and V	Prw and V	Prw	Prw	Prw	Prw	Prw	Prw	0	0	0	0
91	Prw and V	Prw and V	Prw	Prw	Prw	Prw	Prw	Prw	0	0	Prw	0
92	Prw, V and Bw	Bw	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	0	Prw	Prw	Prw
93	Pc and Prw	Pc	Pc and Prw	Prw	Prw	Prw	Prw	Prw	0	Prw	0	0
94	Pc and Prw	Pc	Pc and Prw	Prw	Prw	Prw	Prw	Prw	0	Prw	0	0
95	Pc, Prw and Bw	Pc and Bw	Pc	Pc	Prw	Pc and Prw	Prw	Prw	0	Prw	0	Prw
96	Pc, Prw and Bw	Pc and Bw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Prw	0	Prw
97	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T		
98	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	Pc and T	Pc and T	Pc and T	0	0
99	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
100	Pc, T and Bw	Bw	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	0	0
101	Pc, T and Bw	Pc, T and Bw	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
102	Pc and Prw	Pc	Pc	Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0
103	Pc, Prw and Bw	Pc and Bw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Prw	0	0
104	Pc, Prw and Bw	Bw	Bw	Prw	Pc and Prw	Prw	Prw	Prw	0	Prw	0	0
105	Pc, Prw and T	Pc	Pc and T	Pc, Prw and T	Pc, Prw and T	Pc, Prw and T	Prw and T	Prw and T	T	Prw and T	0	0
106	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
107	Pc and Prw	Pc	Pc and Prw	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	0	0
108	Pc, Prw and Bw	Pc and Bw	Pc	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Prw	Prw	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (G) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
109	Pc, Prw and Bw	Pc and Bw	Pc	Pc	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Prw	Prw	0
110	Pc, Prw and Bw	Pc and Bw	Pc	Pc	Prw	Prw	Prw	Prw	Pc and Prw	Prw	0	0
111	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
112	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0
113	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc
114	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc
115	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0
116	Pc, Prw and Bw	Pc and Bw	Pc	Pc and Prw	Prw	Prw	Prw	Prw	0	Prw	0	Prw
117	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
118	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	0	0	0	0
119	Pc, Prw and Ss	Ss	Ss	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and	0	0	0	0
120	Pc, Prw and Ss	Pc	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and Ss	Pc, Prw and Ss	0	Prw	0	0
121	Pc, Prw and Ss	Pc	Pc and Ss	Prw and Ss	Prw and Ss	Prw and Ss	Prw and Ss	Prw and Ss	0	Prw	0	0
122	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	0	Pc and Ss	0	0
123	Ss and V	Ss	Ss and V	Ss and V	Ss and V	Ss and V	Ss	Ss	0	0	0	0
124	Prw	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	0
125	Pc and Prw	Pc	Pc	Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Pc and Prw	Pc and Prw	0
126	Pc, Prw and Bw	Pc and Bw	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	0	0
127	Pc, Prw and Bw	Pc and Bw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Prw	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (H) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
128	Pc, T and Bw	Bw	Bw	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
129	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
130	Ps and Cw	Ps	Ps	Ps and Cw	Ps and Cw	Cw	Cw	Cw	0	Cw	Ps and Cw	Cw
131	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	0	0
132	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	0	0
133	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
134	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
135	Cw and Ss	Cw	Cw	Cw	Cw	Cw and Ss	Cw	Cw and	0	Cw	0	0
136	Cw	Cw	Cw	Cw	Cw	Cw	Cw	Cw	Cw	Cw	Cw	0
137	Cw and Ss	Cw	Cw	Cw	Cw	Cw and Ss	Cw and Ss	Cw and	Ss	Cw and Ss	Cw and Ss	Cw and Ss
138	Cw and Ss	Cw	Cw	Cw and Ss	Cw and Ss	Cw and Ss	Cw and Ss	Cw and	Cw and Ss	Cw and Ss	0	0
139	Cw and Ss	Cw	Cw	Cw	Cw and Ss	Cw and Ss	Cw and Ss	Cw	0	Cw	0	0
140	Pc, Ss and Bw	Pc and Bw	Pc	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc	Ss
141	Ss and V	Ss and V	Ss and V	Ss and V	Ss and V	Ss and V	Ss and V	Ss	0	0	0	0
142	Pc, Ss and Bw	Pc and Bw	Pc	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and	Pc and Ss	Ss	Ss	Ss
143	Pc, T and Ss	Pc	Pc	Pc, T and Ss	Pc, T and Ss	Pc, T and Ss	Pc	Pc	Pc	Pc	0	0
144	Pc, T and Ss	Pc	Pc	Pc, T and Ss	Pc, T and Ss	Pc, T and Ss	Pc, T and Ss	Pc, T and	Pc, T and Ss	Pc, T and Ss	0	0
145	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	Prw	Prw
146	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and	0	Pc	0	0
147	Prw and Bw	Bw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	0	Prw
148	Ss	Ss	Ss	Ss	Ss	Ss	Ss	Ss	0	0	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (I) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
149	Prw and Bw	Bw	Prw and Bw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	0	0
150	Prw and Bw	Prw and Bw	Prw	Prw	Prw	Prw	Prw	Prw	0	0	0	0
151	Prw and Bw	Bw	Prw	Prw	Prw	Prw	Prw	Prw	0	Prw	0	Prw
152	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	0	Pc and Ss	0	0
153	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	0	0	0
154	Pc and Ss	Pc and Ss	Pc and Ss	Pc and Ss	Ss	Ss	Ss	Ss	0	Pc	0	0
155	Pc, Prw and Bw	Pc and Bw	Pc	Prw	Prw	Prw	Prw	Prw	0	Prw	0	Prw
156	Pc, Prw and Bw	Bw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Prw	0	Prw
157	Prw and Bw	Prw and Bw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	0
158	Prw	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	PrW	0	0
159	Prw and Bw	Bw	Prw and Bw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	0
160	Prw and T	T	T	T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	0	0
161	Pc, T and Bw	Bw	Pc and t	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc	0
162	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps
163	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	Ps	0
164	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	0	0
165	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	Ps	0
166	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	Ps	0
167	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
168	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
169	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
170	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (J) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
171	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
172	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0
173	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
174	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
175	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	Pc	0
176	Pc, V and Bw	Pc and Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	Pc	Pc
177	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	Prw	0
178	Pc, Prw and Bw	Bw	Pc	Pc and Prw	Pc and Prw	Prw	Prw	Prw	Pc and Prw	Prw	Prw	Prw
179	Pc, Prw and Bw	Pc and Bw	Pc	Pc and Prw	Prw	Prw	Prw	Prw	0	Prw	Prw	0
180	Pc, Prw and T	Pc and T	Pc and T	Prw and T	Prw and T	Prw and T	Prw and T	Prw and T	Pc, Prw and T	Prw and T	0	0
181	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	Pc
182	Pc, Prw and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc and Prw	Pc	Prw	Prw	Prw
183	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	T
184	Pc, Prw and V	Pc and V	Pc and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	0	Prw
185	Pc, Prw and V	Pc	Pc	Pc, Prw and V	Pc, Prw and V	Pc, Prw and V	Prw	Pc, Prw and V	0	V and Prw	0	0
186	Pc, V and Bw	Bw	Bw	Pc and V	Pc and V	Pc and V	Pc and V	Pc and V	0	Pc and V	0	0
187	T and Bw	Bw	Bw	T	T	T	T	T	T	T	T	T
188	Prw and Bw	Bw	Prw	Prw	Prw	Prw	Prw	Prw	0	0	0	0
189	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	0	0	0
190	Pc, T and Bw	Bw	Pc	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	0	0

Pc: Private connection; Ps: Public supply; PrW: Private well; V: Vendor; T: Tanker; Ss: Stone spout; Cw: Public well; Bw: Bottled water

Appendix III (K) Water supply sources and their purposes

Respondent no.	Source combination	Drinking	Cooking	Bathing	Hygiene	Laundry	Dishwash	Toilet	Religious activities	House cleaning	Gradening	Car/Bike cleaning
191	Ps and Cw	Ps	Ps	Ps and Cw	Ps and Cw	Cw	Cw	Cw	Cw	Cw	Ps and Cw	Cw
192	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
193	Ps and Cw	Ps	Ps	Ps and Cw	Ps and Cw	Cw	Cw	Cw	Cw	Cw	Ps and Cw	Cw
194	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
195	Ps and Cw	Ps	Ps	Ps and Cw	Ps and Cw	Cw	Cw	Cw	0	Cw	Ps and Cw	Cw
196	Pc and Cw	Pc	Pc	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	Pc and Cw	0	Pc and Cw	0	0
197	Pc, Prw and Bw	Bw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Prw	Prw	Prw
198	Pc and Prw	Pc	Pc and Prw	Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Pc and Prw	0	0
199	Pc and Bw	Pc and Bw	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	0
200	Pc, Prw and Bw	Bw	Pc	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	Pc and Prw	0	Prw	Prw	0
201	Ps and Prw	Ps	Ps	Ps	Ps	Ps	Prw	Prw	Ps	Prw	0	Prw
202	Pc	Pc	Pc	Pc	Pc	Pc	Pc	Pc	0	Pc	0	0
203	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	Pc and Ps	0	0
204	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0	0
205	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	Ps	0	0	0
206	Pc and Prw	Pc	Pc and Prw	Prw	Prw	Prw	Prw	Prw	Pc and Prw	Prw	Prw	0
207	Ps and Prw	Ps	Ps and Prw	Prw	Prw	Prw	Prw	Prw	Ps and Prw	Prw	0	Prw
208	Prw and Bw	Bw	Prw	Prw	Prw	Prw	Prw	Prw	0	Prw	0	Prw
209	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	Pc and Prw	0	0	0
210	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	0	0	0	0
211	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	0	0	0	0
212	Prw and Bw	Bw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	Prw	0	Prw
213	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	Pc and T	0	0
214	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	Prw and V	0	0	0	0
215	Pc, Prw and V	Pc	Pc and V	Prw	Prw	Prw	Prw	Prw	0	V and Prw	0	0
216	Pc and Prw	Pc	Pc	Prw	Prw	Prw	Prw	Prw	0	0	0	0
217	Prw, T and Bw	Pc and Bw	Bw	Prw and T	Prw and T	Prw and T	Prw	Prw	Prw and T	Prw and T	Prw	0

Pc: Private connection; *Ps*: Public supply; *PrW*: Private well; *V*: Vendor; *T*: Tanker; *Ss*: Stone spout; *Cw*: Public well; *Bw*: Bottled water

Appendix IV (A) Socio-economic characteristics of respondents

Respondent no.	Monthly Income	Housing ownerhsip	Family size	No. of male	No. of of female	Elder (Above 60 years)	Adult (15-60 years)	No. of below 15 years	Number of occupants	Education	Total area (m^2)	Area of roof (m^2)
1	12000	O	5	2	3	0	5	0	13	11	207.4	79.5
2	8000	R	3	2	1	0	2	1	9	5	63.6	63.6
3	50000	O	8	3	5	0	5	3	8	14	144.1	108.1
4	25000	O	5	3	2	0	4	1	8	17	262.2	190.7
5	22000	R	4	3	1	0	3	1	8	8	161.0	95.4
6	16000	R	4	3	1	0	4	0	12	12	224.5	79.5
7	35000	O	4	2	2	2	2	0	4	10	46.7	63.6
8	16000	R	5	4	1	0	5	0	9	11	127.2	63.6
9	45000	O	3	1	2	2	1	0	5	17	95.4	95.4
10	35000	O	5	3	2	0	3	2	16	14	160.6	95.4
11	17000	R	5	3	2	0	5	0	8	10	160.0	143.1
12	12000	R	4	3	1	0	4	0	10	11	71.0	71.0
13	10000	R	2	1	1	0	2	0	5	12	190.7	190.7
14	8000	R	5	3	2	0	3	2	4	15	79.5	79.5
15	10000	R	2	1	1	0	2	0	12	17	63.6	63.6
16	15000	R	3	2	1	0	3	0	6	14	79.5	79.5
17	8000	O	4	2	2	0	3	1	8	0	80.5	63.6
18	10000	O	4	2	2	0	4	0	4	12	95.4	95.4
19	10000	O	5	3	2	0	5	0	5	5	31.8	31.8
20	12000	O	5	2	3	0	5	0	5	5	95.4	95.4
21	20000	O	5	2	3	0	4	1	5	10	190.7	127.2
22	8000	R	3	1	2	0	2	1	7	12	71.0	71.0
23	18000	O	5	3	2	0	4	0	14	15	127.2	127.2
24	12000	R	2	1	1	0	2	0	14	12	111.3	111.3
25	10000	R	2	1	1	0	2	0	16	12	46.7	63.6
26	15000	R	5	2	3	0	3	2	8	15	111.3	111.3
27	16000	R	5	3	2	2	3	0	10	17	118.7	95.4
28	30000	O	5	3	2	0	5	0	6	15	245.3	47.7
29	25000	R	2	1	1	0	2	0	22	10	113.4	95.4
30	35000	O	6	2	4	0	4	2	16	15	110.3	101.7
31	55000	O	4	3	1	1	3	0	15	15	110.3	127.2
32	15000	R	3	1	2	0	2	1	10	14	161.0	95.4
33	25000	R	5	3	2	2	2	1	8	17	143.1	95.4
34	15000	R	4	2	2	0	4	0	16	10	63.6	63.6
35	12000	R	4	2	2	0	4	0	16	15	77.5	111.3
36	45000	O	5	2	3	1	3	1	8	17	146.9	115.0
37	8000	R	4	2	2	0	4	2	8	10	63.6	63.6
38	10000	R	3	1	2	0	2	1	16	15	80.5	63.6
39	8000	R	4	2	2	0	3	1	11	12	159.0	159.0
40	10000	R	6	3	3	0	4	2	16	15	111.3	111.3
41	10000	R	6	4	2	0	4	2	12	17	190.7	108.1
42	24000	O	3	2	1	2	1	0	3	5	79.5	79.5
43	12000	O	3	1	2	0	3	0	3	11	47.7	47.7
44	10000	R	2	2	0	0	2	0	5	16	95.4	95.4
45	20000	R	5	3	2	0	3	2	10	14	71.0	71.0

Appendix IV (B) Socio-economic characteristics of respondents

Respondent no.	Monthly Income	Housing ownerhsip	Family size	No. of male	No. of of female	Elder (Above 60 years)	Adult (15-60 years)	No. of below 15 years	Number of occupants	Education	Total area (m^2)	Area of roof (m^2)
46	18000	R	5	3	2	0	3	2	12	13	95.4	95.4
47	55000	O	3	2	1	0	2	1	16	17	113.1	130.0
48	30000	O	6	3	3	0	4	2	12	7	127.2	111.3
49	100000	O	8	3	5	0	6	2	8	15	143.7	95.4
50	15000	R	7	3	4	1	4	3	8	8	95.4	95.4
51	20000	O	5	3	2	0	3	2	8	17	63.6	63.6
52	35000	O	6	2	4	1	4	1	6	12	127.2	79.5
53	18000	R	4	2	2	0	3	1	12	12	79.5	79.5
54	8000	R	7	3	4	0	4	3	12	6	111.3	111.3
55	10000	R	4	2	2	0	2	2	8	17	63.6	63.6
56	22000	R	3	2	1	0	3	0	13	14	127.2	79.5
57	15000	R	3	1	2	0	3	0	12	15	111.3	79.5
58	60000	R	5	3	2	0	4	1	10	20	254.4	190.7
59	18000	R	5	2	3	1	3	1	11	12	112.3	95.4
60	20000	O	4	2	2	0	2	2	4	10	79.5	79.5
61	14000	R	3	2	1	0	3	0	12	14	111.3	111.3
62	50000	O	6	4	2	1	4	1	8	15	190.7	190.7
63	50000	O	4	1	3	0	4	0	12	17	127.2	127.2
64	24000	R	5	2	3	0	3	2	8	17	190.7	95.4
65	12000	R	4	2	2	0	3	1	12	12	63.6	63.6
66	16000	O	4	2	2	0	2	2	16	12	95.4	95.4
67	10000	R	6	3	3	0	3	3	12	5	63.6	63.6
68	30000	O	5	3	2	0	5	0	15	17	95.4	95.4
69	15000	R	2	1	1	0	2	0	9	12	144.1	55.3
70	12000	R	3	2	1	0	3	0	16	14	127.2	79.5
71	36000	O	6	3	3	0	5	1	10	15	159.0	159.0
72	18000	R	4	2	2	0	4	0	8	15	79.5	79.5
73	24000	R	4	1	3	0	2	2	22	17	144.1	95.4
74	12000	O	5	3	2	0	3	2	16	8	63.6	63.6
75	7000	O	3	3	0	0	2	1	6	8	31.8	31.8
76	10000	R	3	2	1	0	3	0	16	17	127.2	63.6
77	10000	O	4	3	1	0	2	2	4	7	79.5	79.5
78	10000	O	8	4	4	0	5	3	8	5	79.5	79.5
79	10000	O	5	3	2	0	4	1	5	10	86.5	95.4
80	18000	O	4	2	2	0	2	2	4	12	95.4	95.4
81	25000	O	5	3	2	0	4	1	5	0	63.7	63.6
82	18000	O	3	2	1	0	3	0	18	11	156.9	127.2
83	10000	R	2	2	0	0	2	0	14	12	63.6	63.6
84	30000	O	5	2	3	0	5	0	16	11	95.4	95.4
85	10000	O	4	3	1	0	2	2	10	0	112.3	95.4
86	15000	O	5	3	2	0	3	2	18	0	78.5	95.4
87	10000	O	7	3	4	0	4	3	7	8	63.6	63.6
88	40000	R	4	2	2	0	2	2	4	17	127.2	127.2
89	30000	R	4	3	1	0	4	0	6	12	190.7	190.7
90	15000	R	3	1	2	0	3	0	19	14	127.2	127.2

Appendix IV (C) Socio-economic characteristics of respondents

Respondent no.	Monthly Income	Housing ownerhsip	Family size	No. of male	No. of of female	Elder (Above 60 years)	Adult (15-60 years)	No. of below 15 years	Number of occupants	Education	Total area (m^2)	Area of roof (m^2)
91	5000	R	8	5	3	0	6	2	22	8	111.3	111.3
92	18000	R	4	2	2	0	3	1	13	16	238.4	190.7
93	13000	R	4	2	2	0	3	1	11	5	194.8	95.4
94	15000	R	3	1	2	0	2	1	7	5	175.9	159.0
95	15000	R	3	2	1	0	3	0	12	17	95.4	95.4
96	15000	R	3	2	1	0	2	1	8	5	143.1	95.4
97	45000	R	5	2	3	0	4	1	12	17	143.7	143.7
98	60000	O	5	2	3	0	5	0	12	12	163.8	111.3
99	32000	O	4	2	2	1	3	0	18	10	127.2	127.2
100	20000	R	5	2	3	2	3	0	16	12	161.0	127.2
101	35000	O	5	3	2	2	2	1	8	6	143.7	111.3
102	55000	O	3	1	2	1	2	0	7	17	127.2	95.4
103	20000	R	3	1	2	0	3	0	9	17	143.7	63.6
104	30000	R	4	2	2	1	2	1	12	17	127.2	95.4
105	38000	R	4	2	2	2	2	0	14	12	190.7	127.2
106	10000	R	5	2	3	0	5	0	12	10	82.6	95.4
107	28000	O	10	4	6	4	4	2	18	5	101.3	95.4
108	27000	O	4	3	1	0	4	0	8	15	190.7	95.4
109	30000	O	5	2	3	2	2	1	15	5	158.9	127.2
110	30000	O	5	3	2	2	2	1	16	15	127.2	95.4
111	15000	R	3	2	1	0	2	1	5	10	71.0	71.0
112	32000	O	4	1	3	0	4	0	10	17	78.5	95.4
113	35000	O	4	2	2	1	3	0	8	17	190.7	190.7
114	24000	O	4	3	1	2	2	0	12	5	71.0	71.0
115	25000	O	2	1	1	0	2	0	8	17	87.4	95.4
116	15000	R	5	3	2	1	3	1	8	17	111.3	79.5
117	35000	O	5	3	2	0	3	2	4	8	95.4	95.4
118	12000	R	5	2	3	0	3	2	10	5	127.2	127.2
119	10000	R	6	3	3	0	6	0	12	15	95.4	47.7
120	8000	R	4	2	2	0	4	0	16	0	143.1	95.4
121	8000	R	4	3	1	0	2	2	13	10	95.4	31.8
122	8500	R	5	2	3	0	2	3	12	5	95.4	95.4
123	10000	R	5	3	2	0	3	2	8	5	95.4	95.4
124	70000	O	12	6	6	2	5	5	12	15	111.3	111.3
125	45000	R	5	2	3	0	5	0	12	15	161.0	127.2
126	25000	O	3	2	1	0	3	0	12	13	143.7	63.6
127	35000	O	5	2	3	0	5	0	12	15	159.0	95.4
128	35000	O	5	2	3	2	3	0	8	12	103.9	95.4
129	15000	R	4	3	1	0	2	2	7	10	63.6	63.6
130	20000	O	5	3	2	0	4	1	5	8	47.7	47.7
131	10000	O	5	3	2	0	5	0	5	8	84.5	79.5
132	10000	O	6	3	3	0	5	1	6	5	71.0	79.5
133	10000	O	3	2	1	0	3	0	8	15	111.3	111.3
134	8000	O	5	4	1	0	3	2	9	10	79.5	79.5
135	18000	R	4	1	3	1	2	1	12	8	86.9	95.4

Appendix IV (D) Socio-economic characteristics of respondents

Respondent no.	Monthly Income	Housing ownerhsip	Family size	No. of male	No. of of female	Elder (Above 60 years)	Adult (15-60 years)	No. of below 15 years	Number of occupants	Education	Total area (m^2)	Area of roof (m^2)
136	16000	O	3	2	1	0	2	1	8	12	95.4	95.4
137	18000	O	5	2	3	2	3	0	4	8	71.0	71.0
138	20000	O	4	1	3	0	4	0	4	5	63.6	63.6
139	15000	R	5	2	3	0	4	1	12	0	40.0	40.0
140	20000	O	6	2	4	2	3	1	8	12	79.5	79.5
141	18000	R	8	5	3	2	4	2	9	6	63.6	63.6
142	18000	O	4	1	3	1	2	1	4	10	63.6	63.6
143	30000	O	5	3	2	0	5	0	5	11	190.7	190.7
144	25000	O	6	3	3	1	5	0	6	8	143.7	143.7
145	28000	O	5	3	2	0	5	0	9	16	146.1	95.4
146	16000	R	4	2	2	0	2	2	8	15	83.4	95.4
147	20000	O	4	1	3	1	3	0	8	16	120.2	127.2
148	8000	R	4	3	1	0	2	2	12	6	63.6	63.6
149	48000	O	4	2	2	2	2	0	8	15	118.9	63.6
150	15000	R	2	1	1	0	2	0	16	5	190.7	79.5
151	20000	R	5	2	3	0	4	1	7	10	111.3	111.3
152	8000	R	6	2	4	0	3	3	13	12	100.4	79.5
153	28000	O	10	5	5	2	5	2	16	15	127.2	127.2
154	6000	R	6	2	4	0	3	3	8	15	105.4	95.4
155	15000	R	4	2	2	0	4	0	20	16	111.3	95.4
156	12000	R	6	3	3	0	4	2	8	12	159.0	95.4
157	35000	O	5	2	3	1	3	1	8	8	123.3	111.3
158	32000	O	5	3	2	1	4	0	5	12	190.7	95.4
159	35000	O	5	2	3	0	5	0	8	12	143.1	95.4
160	40000	O	8	4	4	2	4	2	8	15	149.7	111.3
161	50000	O	5	1	4	0	5	0	8	10	112.3	95.4
162	10000	O	5	3	2	1	4	0	5	5	190.3	190.3
163	12000	O	4	2	2	0	3	1	8	15	63.6	63.6
164	10000	O	5	2	3	0	5	0	16	5	40.0	40.0
165	15000	O	6	2	4	0	4	2	6	5	139.2	127.2
166	18000	O	5	2	3	2	3	0	12	10	111.3	111.3
167	20000	R	4	2	2	0	4	0	4	15	95.4	95.4
168	12000	R	2	1	1	0	2	0	8	15	143.1	111.3
169	12000	R	4	2	2	0	2	2	4	17	47.7	47.7
170	10000	R	4	2	2	0	2	2	7	12	78.5	95.4
171	25000	R	4	2	2	0	4	0	10	15	73.6	63.6
172	25000	O	4	2	2	0	4	0	11	12	106.3	95.4
173	10000	R	2	1	1	0	2	0	7	12	63.6	63.6
174	12000	R	4	2	2	0	4	0	8	5	79.5	79.5
175	20000	R	6	2	4	2	4	0	10	17	80.4	95.4
176	16000	R	3	1	2	0	2	1	16	15	79.5	79.5
177	25000	O	6	4	2	0	4	2	10	12	159.0	135.1
178	60000	O	9	5	4	2	5	2	9	15	127.2	63.6
179	23000	R	5	2	3	1	3	1	8	15	159.0	127.2
180	40000	O	6	3	3	2	3	1	15	15	112.3	76.3

Appendix IV (E) Socio-economic characteristics of respondents

Respondent no.	Monthly Income	Housing ownerhsip	Family size	No. of male	No. of of female	Elder (Above 60 years)	Adult (15-60 years)	No. of below 15 years	Number of occupants	Education	Total area (m^2)	Area of roof (m^2)
181	16000	R	4	2	2	0	3	1	6	10	127.2	127.2
182	28000	O	5	2	3	0	4	1	5	15	127.2	101.7
183	65000	O	3	1	2	0	3	0	10	7	127.2	127.2
184	15000	O	4	2	2	0	2	2	12	5	143.1	143.1
185	25000	R	5	3	2	0	4	1	8	15	127.2	127.2
186	25000	R	5	3	2	0	5	0	5	17	112.3	95.4
187	65000	O	4	2	2	0	4	0	8	10	143.7	143.1
188	30000	R	5	2	3	1	3	1	12	10	126.2	95.4
189	60000	O	5	2	3	1	2	2	12	15	117.2	95.4
190	25000	R	5	2	3	2	2	1	8	12	128.2	111.3
191	15000	O	4	2	2	0	2	2	15	5	63.6	63.6
192	10000	O	6	3	3	1	3	2	6	10	63.6	63.6
193	18000	O	6	3	3	1	3	2	6	5	79.5	79.5
194	10000	O	6	2	4	0	4	2	6	13	63.6	63.6
195	15000	O	4	2	2	0	2	2	4	5	95.4	95.4
196	14000	R	5	3	2	0	3	2	16	8	143.7	143.7
197	28000	O	6	3	3	2	3	1	12	5	90.4	95.4
198	14000	R	6	3	3	0	5	1	8	15	100.4	95.4
199	10000	R	4	2	2	0	4	0	5	17	80.5	63.6
200	25000	R	4	2	2	1	2	1	12	12	143.7	95.4
201	25000	R	5	2	3	0	3	2	10	12	63.6	63.6
202	20000	R	3	2	1	0	2	1	3	12	79.5	79.5
203	10000	O	8	3	5	0	5	3	10	5	63.6	63.6
204	18000	O	4	1	3	0	4	0	7	8	85.4	95.4
205	12000	O	4	2	2	1	2	1	5	0	127.2	127.2
206	15000	O	5	3	2	0	3	2	5	5	245.3	79.5
207	12000	O	4	2	2	1	3	0	8	5	79.5	79.5
208	16000	R	3	2	1	0	2	1	8	15	159.0	159.0
209	22000	O	4	1	3	0	4	0	14	6	286.1	95.4
210	15000	R	2	1	1	0	2	0	8	5	110.3	127.2
211	16000	R	5	2	3	0	5	0	16	10	111.3	111.3
212	20000	R	3	2	1	0	2	1	12	10	127.2	47.7
213	10000	R	6	3	3	2	4	0	12	17	143.7	143.7
214	12000	R	8	3	5	2	3	3	19	17	190.7	95.4
215	15000	R	3	1	2	0	3	0	16	17	127.2	95.4
216	17000	R	3	3	0	0	3	0	8	17	159.0	127.2
217	45000	O	5	2	3	2	3	0	10	17	144.1	127.2

Appendix V (A) Water consumption for potable and non-potable purposes

Respondents no.	Vol. of potable (L/c/d)	Vol. of Non-potable (L/c/d)	Water supply sources: Private pipe connection		Bottled water		Vendor/ Tanker		Community sources		Public standpipe		Private well	
			1	2	1	2	1	2	1	2	1	2	1	2
2	3.3	13.3	150.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	4.4	20.0	70.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	1.0
6	3.8	26.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0
8	5.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	175.0	1.0
11	4.7	15.3	300.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	4.5	16.3	250.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	6.0	27.5	200.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	5.7	19.3	375.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	5.8	9.2	90.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	6.7	28.3	300.0	3.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	12.9	25.0	103.0	30.0	0.0	0.0	0.0	0.0	300.0	3.0	0.0	0.0	0.0	0.0
18	3.7	35.0	80.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	4.8	28.0	100.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	4.9	13.8	280.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	4.0	14.0	220.0	30.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	5.6	28.5	45.0	4.0	0.0	0.0	285.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
25	6.9	26.3	55.0	4.0	0.0	0.0	210.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
26	3.5	13.3	50.0	4.0	20.0	4.0	400.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
27	7.2	20.0	180.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	1.0
29	1.4	18.0	0.0	5.0	20.0	7.0	225.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0
32	4.8	38.3	100.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.0	1.0
33	10.0	28.0	275.0	7.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	140.0	1.0
34	6.6	20.0	185.0	7.0	0.0	0.0	160.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
35	5.2	15.4	145.0	7.0	0.0	0.0	430.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0
37	4.3	20.8	400.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	5.4	22.1	330.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	7.5	39.2	0.0	0.0	0.0	0.0	90.0	3.0	0.0	0.0	0.0	0.0	470.0	3.0
40	2.5	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	115.0	1.0
41	4.2	19.4	0.0	0.0	0.0	0.0	50.0	2.0	0.0	0.0	0.0	0.0	350.0	3.0
44	6.0	19.0	150.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	6.2	26.3	155.0	5.0	0.0	0.0	395.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
46	4.4	18.0	110.0	5.0	0.0	0.0	360.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
47	12.3	48.0	180.0	5.0	0.0	0.0	10000.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0
50	6.4	18.6	0.0	7.0	20.0	2.0	0.0	0.0	160.0	1.0	0.0	0.0	0.0	0.0
52	8.3	22.9	40.0	7.0	20.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	275.0	2.0
53	5.4	21.3	0.0	7.0	20.0	3.0	0.0	0.0	100.0	1.0	0.0	0.0	0.0	0.0

1:Volume of water (L); 2: Days of interval for fetching or purchasing

Appendix V (B) Water consumption for potable and non-potable purposes

Respondents no.	Vol. of potable (L/c/d)	Vol. of Non-potable (L/c/d)	Water supply sources: Private pipe connection		Bottled water		Vendor/ Tanker		Community sources		Public standpipe		Private well	
			1	2	1	2	1	2	1	2	1	2	1	2
54	2.9	20.0	150.0	7.0	0.0	0.0	0.0	0.0	105.0	1.0	0.0	0.0	0.0	0.0
55	3.4	9.8	210.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	5.0	28.3	60.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.0	1.0
59	6.0	18.0	100.0	4.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0	1.0
61	5.6	40.0	90.0	7.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0
64	4.3	12.0	150.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	1.0
65	6.4	16.3	180.0	7.0	0.0	0.0	0.0	0.0	65.0	1.0	0.0	0.0	0.0	0.0
66	7.9	17.9	125.0	30.0	0.0	0.0	0.0	0.0	500.0	7.0	0.0	0.0	0.0	0.0
67	6.0	23.3	250.0	7.0	0.0	0.0	0.0	0.0	140.0	1.0	0.0	0.0	0.0	0.0
69	4.4	47.5	0.0	0.0	20.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	200.0	2.0
70	13.0	51.7	0.0	0.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	570.0	3.0
72	4.3	22.5	120.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90.0	1.0
73	7.1	28.0	200.0	7.0	0.0	0.0	3000.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
74	5.0	15.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	1.0	0.0	0.0
75	6.7	33.3	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0	0.0	0.0
83	5.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	160.0	5.0	0.0	0.0
90	5.0	NA	0.0	0.0	0.0	0.0	15.0	1.0	0.0	0.0	0.0	0.0	NA	NA
91	2.8	11.3	0.0	0.0	0.0	0.0	225.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
92	5.8	25.0	0.0	0.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	250.0	3.0
93	4.3	30.0	85.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0
94	4.8	15.0	100.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0	1.0
95	3.1	15.0	30.0	7.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0	1.0
96	4.0	21.7	50.0	7.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	195.0	3.0
98	8.5	38.4	90.0	7.0	0.0	0.0	8000.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
100	5.7	50.0	130.0	7.0	20.0	2.0	8000.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
102	8.5	18.9	185.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	2.0
103	10.0	36.7	125.0	5.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	1.0
104	6.2	30.0	90.0	5.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0
105	6.3	33.8	125.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	135.0	1.0
106	2.2	9.8	260.0	5.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
110	11.4	60.0	150.0	5.0	20.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	600.0	2.0
111	7.3	24.0	375.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
113	8.2	27.5	250.0	4.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
114	5.9	20.0	300.0	30.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
116	6.8	22.0	210.0	7.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	1.0
118	4.0	20.0	100.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	1.0
119	3.3	12.5	0.0	5.0	0.0	0.0	40.0	2.0	0.0	0.0	0.0	0.0	150.0	2.0
122	5.8	21.2	145.0	5.0	0.0	0.0	0.0	0.0	130.0	1.0	0.0	0.0	0.0	0.0

1:Volume of water (L); 2: days of interval for fetching or purchasing

Appendix V (C) Water consumption for potable and non-potable purposes

Respondents no.	Vol. of potable (L/c/d)	Vol. of Non-potable (L/c/d)	Water supply sources: Private pipe connection		Bottled water		Vendor/ Tanker		Community sources		Public standpipe		Private well	
			1	2	1	2	1	2	1	2	1	2	1	2
124	9.2	28.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	450.0	1.0
125	7.1	42.0	250.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	210.0	1.0
126	7.5	41.7	140.0	7.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	250.0	2.0
128	9.1	25.0	250.0	7.0	20.0	2.0	8000.0	40.0	0.0	0.0	0.0	0.0	0.0	0.0
129	5.6	24.4	480.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
135	7.5	42.5	0.0	0.0	0.0	0.0	0.0	0.0	200.0	1.0	0.0	0.0	0.0	0.0
137	6.0	39.0	0.0	0.0	0.0	0.0	0.0	0.0	225.0	1.0	0.0	0.0	0.0	0.0
138	8.8	46.3	0.0	0.0	0.0	0.0	0.0	0.0	220.0	1.0	0.0	0.0	0.0	0.0
139	7.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	190.0	1.0	0.0	0.0	0.0	0.0
140	10.8	15.0	85.0	5.0	0.0	0.0	0.0	0.0	180.0	2.0	0.0	0.0	0.0	0.0
141	5.0	15.0	0.0	0.0	0.0	0.0	240.0	2.0	40.0	1.0	0.0	0.0	0.0	0.0
142	5.4	15.0	0.0	0.0	20.0	3.0	0.0	0.0	225.0	3.0	0.0	0.0	0.0	0.0
146	8.8	26.8	245.0	7.0	0.0	0.0	0.0	0.0	160.0	1.0	0.0	0.0	0.0	0.0
147	11.0	40.0	0.0	0.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	185.0	1.0
148	6.3	23.8	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0	0.0	0.0	0.0	0.0
149	12.2	72.5	0.0	0.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	1000.0	3.0
150	4.7	36.5	0.0	0.0	20.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	240.0	3.0
151	5.2	36.0	0.0	0.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	600.0	3.0
152	1.3	27.2	40.0	5.0	0.0	0.0	0.0	0.0	210.0	1.0	0.0	0.0	0.0	0.0
154	2.0	26.3	60.0	5.0	0.0	0.0	0.0	0.0	90.0	1.0	0.0	0.0	0.0	0.0
155	3.8	18.8	50.0	5.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	1.0
156	3.8	20.8	80.0	5.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	250.0	2.0
157	8.3	31.0	0.0	0.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	350.0	2.0
163	6.3	18.8	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	1.0	0.0	0.0
166	4.6	19.2	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0	0.0	0.0
167	11.8	40.0	800.0	30.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
168	2.0	NA	0.0	3.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
169	8.0	32.6	650.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
170	3.1	9.4	200.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
171	6.7	21.3	400.0	4.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
173	3.4	15.0	140.0	4.0	20.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
174	3.2	14.5	300.0	4.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
175	1.1	NA	0.0	4.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
176	8.6	36.1	180.0	7.0	0.0	0.0	325.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
178	5.5	27.8	275.0	7.0	20.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	500.0	2.0
179	7.4	37.7	225.0	7.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	565.0	3.0
181	4.9	17.5	325.0	4.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
182	5.3	33.3	80.0	4.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	500.0	3.0
183	14.3	48.2	140.0	30.0	0.0	0.0	8000.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0
184	3.8	NA	0.0	4.0	0.0	0.0	15.0	1.0	0.0	0.0	0.0	0.0	NA	NA
185	4.0	20.0	0.0	4.0	0.0	0.0	20.0	1.0	0.0	0.0	0.0	0.0	300.0	3.0

1:Volume of water (L); 2: days of interval for fetching or purchasing

Appendix V (D) Water consumption for potable and non-potable purposes

Respondents no.	Vol. of potable (L/c/d)	Vol. of Non-potable (L/c/d)	Water supply sources: Private pipe connection		Bottled water		Vendor/ Tanker		Community sources		Public standpipe		Private well	
			1	2	1	2	1	2	1	2	1	2	1	2
186	1.3	24.9	0.0	7.0	20.0	3.0	300.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
188	6.8	25.0	0.0	0.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	315.0	2.0
190	12.6	41.7	300.0	7.0	20.0	1.0	5000.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
196	5.2	32.0	130.0	5.0	0.0	0.0	0.0	0.0	160.0	1.0	0.0	0.0	0.0	0.0
197	7.1	20.8	250.0	7.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	250.0	2.0
198	2.4	30.0	100.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	180.0	1.0
199	1.7	NA	0.0	7.0	20.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
201	5.0	35.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	1.0	175.0	1.0
202	4.7	8.7	200.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
204	5.0	15.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	80.0	1.0	0.0	0.0
205	5.0	25.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0	1.0	0.0	0.0
207	5.6	48.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0	2.0	385.0	2.0
208	5.0	26.7	0.0	0.0	20.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	180.0	2.0
210	7.1	27.5	100.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	110.0	2.0
211	4.3	13.0	150.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0	1.0
212	6.3	28.3	0.0	0.0	20.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	1.0
213	5.0	25.6	210.0	7.0	0.0	0.0	5000.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0
214	3.1	21.9	0.0	0.0	0.0	0.0	25.0	1.0	0.0	0.0	0.0	0.0	525.0	3.0
215	13.3	16.7	0.0	7.0	0.0	0.0	40.0	1.0	0.0	0.0	0.0	0.0	100.0	2.0
216	3.3	25.0	70.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	1.0
217	15.0	67.0	0.0	0.0	20.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	390.0	1.0

1:Volume of water (L); 2: days of interval for fetching or purchasing

Appendix VI Micro-components of water consumption for 32 households

Respondent no.	Source combination	Drinking	Cooking	Hygiene	Bath	Laundry	Dishwash	Toilet	Gardening	House cleaning	Religious activities	Car/bike cleaning	Total consumption
8	Ps	1.9	2.6	2.3	5.0	3.6	3.8	5.0	0.0	0.6	0.0	0.6	24.6
22	Pc	1.3	3.3	2.6	2.3	3.2	6.5	2.9	0.0	0.0	0.0	0.0	21.8
35	V	1.8	3.5	5.5	4.6	3.5	6.3	4.9	0.0	0.0	0.0	0.0	30.0
37	Pc	1.2	2.3	4.0	4.8	1.7	3.3	2.9	0.0	0.0	0.0	0.0	20.2
45	V	1.0	4.4	4.4	3.4	6.4	7.9	5.4	0.0	0.0	0.0	0.0	32.9
51	Pc	2.5	5.0	3.0	2.9	5.0	6.3	2.5	0.0	0.0	0.4	0.0	27.5
55	Pc	1.6	2.7	4.3	3.1	2.4	3.2	3.0	0.0	0.0	0.0	0.0	20.3
62	Pc and T	2.0	5.0	2.0	10.7	10.0	6.7	6.7	7.5	0.4	0.2	0.0	51.1
69	Prw and Bw	2.5	6.5	8.4	3.4	5.0	9.3	10.0	0.0	0.0	0.0	0.0	45.1
98	Pc and T	2.3	6.3	10.6	8.9	10.3	12.0	9.0	0.0	0.5	0.2	0.0	60.0
102	Pc and Prw	2.5	6.5	7.5	11.6	7.9	10.0	7.5	4.0	3.3	0.7	0.0	61.5
108	Pc and Prw	1.7	3.3	8.8	4.3	8.9	8.1	10.0	0.0	4.6	0.3	0.0	49.8
111	Pc	2.4	4.2	3.3	2.4	3.5	5.8	3.5	0.0	0.6	0.0	0.0	25.5
112	Pc and Bw	1.8	5.4	4.3	5.5	6.4	6.3	5.0	0.0	0.0	0.2	0.0	34.7
122	Pc and Ss	1.5	5.1	3.9	5.1	6.9	7.4	5.0	0.0	0.0	0.0	0.0	34.9
130	Ps and Cw	1.6	3.5	9.2	8.3	4.3	3.0	8.1	0.0	0.0	0.4	0.0	38.4
146	Pc and Ss	1.3	4.5	3.8	5.9	6.4	6.9	5.0	0.0	0.0	0.0	0.0	33.6
150	Prw and Bw	1.5	5.0	7.5	2.1	7.1	7.5	9.4	0.0	0.0	0.0	0.0	40.1
151	Prw and Bw	1.7	3.0	4.0	5.7	3.8	7.6	10.5	0.0	0.0	0.0	0.0	36.3
172	Pc and Bw	1.5	5.8	4.5	3.9	5.7	9.0	4.5	0.0	0.0	0.5	0.0	35.4
177	Pc and Prw	1.3	4.3	10.0	5.7	5.0	7.5	9.5	0.0	0.0	0.3	0.0	43.5
181	Pc and Bw	1.4	3.3	3.5	5.4	5.4	5.0	5.3	0.0	0.0	0.0	0.0	29.2
183	Pc and T	2.6	8.8	2.0	11.4	7.1	7.5	13.8	0.0	1.8	0.7	0.0	55.7
195	Ps and Cw	1.5	5.0	3.8	5.2	6.2	3.5	7.0	0.0	0.0	0.5	0.0	32.6
196	Pc and Cw	1.3	2.8	3.3	4.8	5.3	3.1	5.0	0.0	0.0	0.0	0.0	25.6
197	Pc and T	1.3	4.9	3.5	6.5	7.6	6.7	5.0	0.0	0.0	0.2	0.0	35.7
200	Pc and Prw	1.2	4.2	7.4	5.3	3.6	7.2	7.2	0.0	0.0	0.0	0.0	36.1
202	Pc	1.2	3.3	5.0	3.1	3.8	8.0	5.0	0.0	0.0	0.0	0.0	29.4
210	Pc and Prw	2.3	7.9	5.2	3.2	6.1	5.2	7.0	0.0	0.0	0.0	0.0	36.9
211	Pc and Prw	1.3	3.6	8.0	3.7	9.1	9.0	8.3	7.5	0.7	0.0	0.3	51.3
216	Pc and Prw	1.0	4.7	5.2	3.6	5.0	6.7	7.1	0.0	0.0	0.0	0.0	33.4
217	Prw and Bw	2.0	7.5	7.5	15.0	7.1	10.0	11.3	5.0	0.0	0.8	0.0	66.2

Pc: Private connection; *Ps*: Public supply; *PrW*: Private well; *V*: Vendor; *T*: Tanker; *Ss*: Stone spout; *Cw*: Public well; *Bw*: Bottled water

Appendix VII (A) Water conservation practices at household level

Respondent no.	Use grey water for toilet	Use grey water for garden	Use rainwater	Use multiple sources	Reduce no. of bath/week	Reduce no. of laundry/week	Increase Storage size	Retrofit	Dig wells	Shift to new place
1	N	N	N	Y	N	N	Y	N	Y	N
2	N	N	Y	N	Y	Y	N	N	N	Y
3	N	N	N	Y	N	N	N	N	Y	N
4	N	N	Y	Y	N	N	N	N	Y	N
5	N	N	Y	Y	N	N	N	N	N	Y
6	N	N	N	N	N	N	N	N	N	Y
7	N	N	Y	Y	N	Y	Y	N	N	N
8	N	N	N	N	N	N	N	N	N	Y
9	Y	N	Y	Y	N	N	N	N	N	N
10	N	N	N	Y	N	N	Y	N	N	N
11	N	N	N	N	Y	Y	N	N	N	Y
12	Y	N	Y	N	Y	Y	N	N	N	N
13	N	N	N	N	Y	Y	N	N	N	Y
14	N	N	N	N	Y	Y	N	N	N	N
15	Y	N	N	N	Y	Y	N	N	N	N
16	N	Y	N	Y	Y	Y	N	N	N	N
17	Y	Y	Y	Y	N	N	N	N	N	N
18	N	N	N	N	Y	Y	Y	N	N	N
19	Y	Y	N	N	Y	Y	N	N	N	N
20	N	Y	Y	Y	Y	Y	N	N	N	N
21	N	N	N	Y	N	N	N	N	N	N
22	N	N	N	N	N	N	N	N	N	N
23	Y	Y	Y	Y	Y	Y	N	N	N	N
24	N	N	N	Y	Y	Y	N	N	N	N
25	N	N	Y	Y	Y	Y	N	N	N	N
26	Y	N	Y	Y	Y	N	Y	N	N	N
27	Y	N	N	Y	N	N	N	N	N	Y
28	N	Y	Y	Y	N	N	Y	N	Y	N
29	Y	Y	N	Y	Y	Y	N	N	N	N
30	N	N	N	Y	N	N	Y	N	Y	N
31	N	Y	N	Y	N	N	Y	N	N	N
32	Y	Y	N	Y	N	Y	N	N	N	Y
33	N	N	N	Y	N	N	N	N	N	N
34	Y	N	N	Y	Y	Y	N	N	N	N
35	N	Y	Y	Y	Y	Y	N	N	N	N
36	Y	Y	Y	Y	N	N	Y	N	N	N
37	N	N	N	N	Y	Y	N	N	N	N
38	N	N	N	Y	Y	Y	N	N	N	N
39	Y	N	Y	Y	Y	Y	N	N	N	N
40	N	N	N	Y	Y	Y	N	N	N	N

Appendix VII (B) Water conservation practices at household level

Respondent no.	Use grey water for toilet	Use grey water for garden	Use rainwater	Use multiple sources	Reduce no. of bath/week	Reduce no. of laundry/week	Increase Storage size	Retrofit	Dig wells	Shift to new place
41	N	N	N	Y	N	N	N	N	N	Y
42	N	N	Y	N	N	N	N	N	N	N
43	N	N	N	N	N	N	N	N	N	N
44	N	N	N	N	N	N	N	N	N	N
45	N	N	N	Y	Y	Y	N	N	N	N
46	Y	N	Y	Y	Y	Y	Y	N	N	N
47	N	N	Y	Y	N	N	Y	N	N	N
48	N	N	Y	Y	N	N	Y	N	Y	N
49	N	N	Y	Y	N	N	N	N	Y	N
50	Y	Y	Y	Y	Y	Y	N	N	N	N
51	Y	N	Y	N	Y	Y	N	N	N	N
52	N	N	Y	Y	Y	N	N	N	N	N
53	N	N	N	Y	Y	Y	N	N	N	N
54	Y	Y	N	Y	Y	Y	N	N	N	N
55	N	N	Y	N	Y	Y	N	N	N	N
56	N	N	N	Y	N	N	N	N	N	Y
57	N	N	N	Y	Y	Y	N	N	N	N
58	N	N	N	Y	N	N	N	N	N	Y
59	N	N	N	Y	Y	Y	N	N	N	N
60	N	N	N	Y	Y	Y	N	N	N	N
61	Y	N	N	Y	N	N	N	N	N	N
62	N	N	N	Y	N	N	N	N	N	N
63	N	N	Y	Y	N	N	Y	N	N	N
64	N	N	Y	Y	Y	Y	N	N	N	N
65	N	N	N	Y	Y	Y	N	N	N	N
66	N	N	Y	Y	N	N	Y	N	N	N
67	Y	N	Y	Y	Y	Y	Y	N	N	N
68	Y	Y	Y	Y	N	N	N	Y	N	N
69	N	N	N	Y	N	N	N	N	N	N
70	Y	N	N	Y	N	N	N	N	N	N
71	Y	N	Y	Y	N	N	N	N	N	N
72	Y	N	Y	Y	N	N	N	N	N	Y
73	N	N	N	Y	N	N	N	N	N	N
74	Y	Y	N	N	N	N	N	N	N	N
75	N	N	N	N	N	N	N	N	N	N
76	Y	N	Y	Y	N	N	N	N	N	N
77	Y	N	Y	N	N	Y	N	N	N	N
78	N	N	N	N	Y	Y	N	N	N	N
79	Y	Y	N	N	N	Y	N	N	N	N
80	N	N	N	Y	Y	Y	N	N	N	N

Appendix VII (C) Water conservation practices at household level

Respondent no.	Use grey water for toilet	Use grey water for garden	Use rainwater	Use multiple sources	Reduce no. of bath/week	Reduce no. of laundry/week	Increase Storage size	Retrofit	Dig wells	Shift to new place
81	N	N	Y	Y	Y	Y	N	N	N	N
82	N	N	N	Y	Y	Y	N	N	Y	N
83	N	N	N	Y	Y	Y	N	N	N	N
84	N	N	N	Y	N	N	N	N	N	N
85	N	N	N	Y	N	Y	N	N	N	N
86	Y	N	N	Y	Y	Y	N	N	N	N
87	Y	N	Y	N	N	Y	N	N	N	N
88	N	N	Y	Y	Y	Y	N	N	N	N
89	N	N	N	Y	N	N	N	N	N	N
90	Y	N	Y	Y	N	N	N	N	N	N
91	Y	Y	N	Y	Y	Y	N	N	N	N
92	Y	Y	Y	Y	N	N	N	N	N	N
93	Y	N	Y	Y	Y	Y	N	N	N	N
94	N	N	N	Y	N	N	N	N	N	N
95	Y	N	N	Y	Y	Y	N	N	N	N
96	Y	N	N	Y	Y	N	Y	N	N	N
97	N	Y	N	Y	Y	Y	N	N	N	N
98	N	N	N	Y	N	N	N	N	N	N
99	Y	Y	Y	Y	N	N	N	N	N	N
100	Y	N	N	Y	N	Y	N	N	N	N
101	N	Y	N	Y	N	N	Y	N	N	N
102	N	N	N	Y	N	N	Y	N	Y	N
103	N	N	Y	Y	N	N	N	N	N	N
104	Y	N	Y	Y	N	N	Y	N	N	N
105	N	N	N	Y	N	N	N	N	N	N
106	Y	Y	N	Y	Y	Y	N	N	N	N
107	N	N	N	Y	N	Y	Y	N	N	N
108	N	Y	Y	Y	N	N	N	N	Y	N
109	N	N	Y	Y	N	Y	Y	N	N	N
110	N	N	Y	Y	N	N	Y	N	Y	N
111	N	N	N	N	Y	Y	N	N	N	N
112	N	Y	N	Y	Y	Y	N	N	N	N
113	Y	N	Y	Y	N	N	Y	N	N	N
114	Y	N	Y	Y	N	Y	N	N	N	N
115	N	N	N	Y	Y	Y	N	Y	N	N
116	Y	N	Y	Y	N	N	N	N	N	N
117	Y	N	Y	Y	N	Y	Y	N	N	N
118	N	N	N	Y	N	N	N	N	N	N
119	Y	N	N	Y	Y	Y	N	N	N	N
120	Y	N	N	Y	Y	Y	N	N	N	Y

VII (D) Water conservation practices at household level

Respondent no.	Use grey water for toilet	Use grey water for garden	Use rainwater	Use multiple sources	Reduce no. of bath/week	Reduce no. of laundry/week	Increase Storage size	Retrofit	Dig wells	Shift to new place
121	N	N	N	Y	Y	Y	Y	N	N	N
122	N	N	N	Y	Y	Y	N	N	N	Y
123	Y	N	N	Y	Y	Y	N	N	N	N
124	N	N	N	N	N	N	N	Y	Y	N
125	N	N	N	Y	Y	Y	N	N	N	N
126	N	N	Y	Y	Y	Y	N	N	Y	N
127	N	N	Y	Y	N	N	Y	N	Y	N
128	N	Y	N	Y	N	N	Y	N	N	N
129	N	N	N	N	N	N	N	N	N	N
130	N	N	N	Y	N	N	N	N	N	N
131	N	N	N	Y	N	N	N	N	N	N
132	N	Y	N	Y	N	N	N	N	N	N
133	N	N	N	N	N	N	N	N	N	N
134	N	N	N	N	N	N	N	N	N	N
135	N	N	Y	Y	Y	Y	N	N	N	N
136	Y	Y	N	N	N	N	N	N	N	N
137	Y	Y	Y	Y	Y	Y	N	N	N	N
138	N	N	Y	Y	Y	Y	N	N	N	N
139	N	N	Y	Y	N	N	N	N	N	N
140	N	N	Y	Y	Y	Y	N	N	N	N
141	Y	N	N	Y	Y	Y	N	N	N	N
142	Y	Y	Y	Y	N	N	Y	N	N	N
143	Y	N	N	Y	Y	Y	Y	N	N	N
144	Y	Y	Y	Y	Y	Y	Y	N	N	N
145	N	Y	Y	Y	Y	Y	N	N	Y	N
146	N	N	N	Y	Y	Y	Y	N	N	Y
147	N	N	N	Y	N	N	N	N	Y	N
148	N	N	N	N	N	N	Y	N	N	N
149	N	N	N	Y	N	N	Y	N	Y	N
150	N	N	Y	Y	Y	Y	N	N	N	N
151	N	N	N	Y	N	Y	N	N	N	N
152	N	N	Y	Y	N	N	N	N	N	N
153	N	N	Y	Y	N	N	N	N	Y	N
154	Y	N	N	Y	Y	Y	N	N	N	N
155	N	N	N	Y	Y	Y	N	N	N	N
156	N	N	N	Y	Y	Y	N	N	N	N
157	N	N	N	Y	Y	Y	N	Y	Y	N
158	N	N	Y	N	N	N	Y	Y	Y	N
159	Y	Y	Y	Y	N	Y	N	N	Y	N
160	N	N	N	Y	N	N	Y	N	Y	N

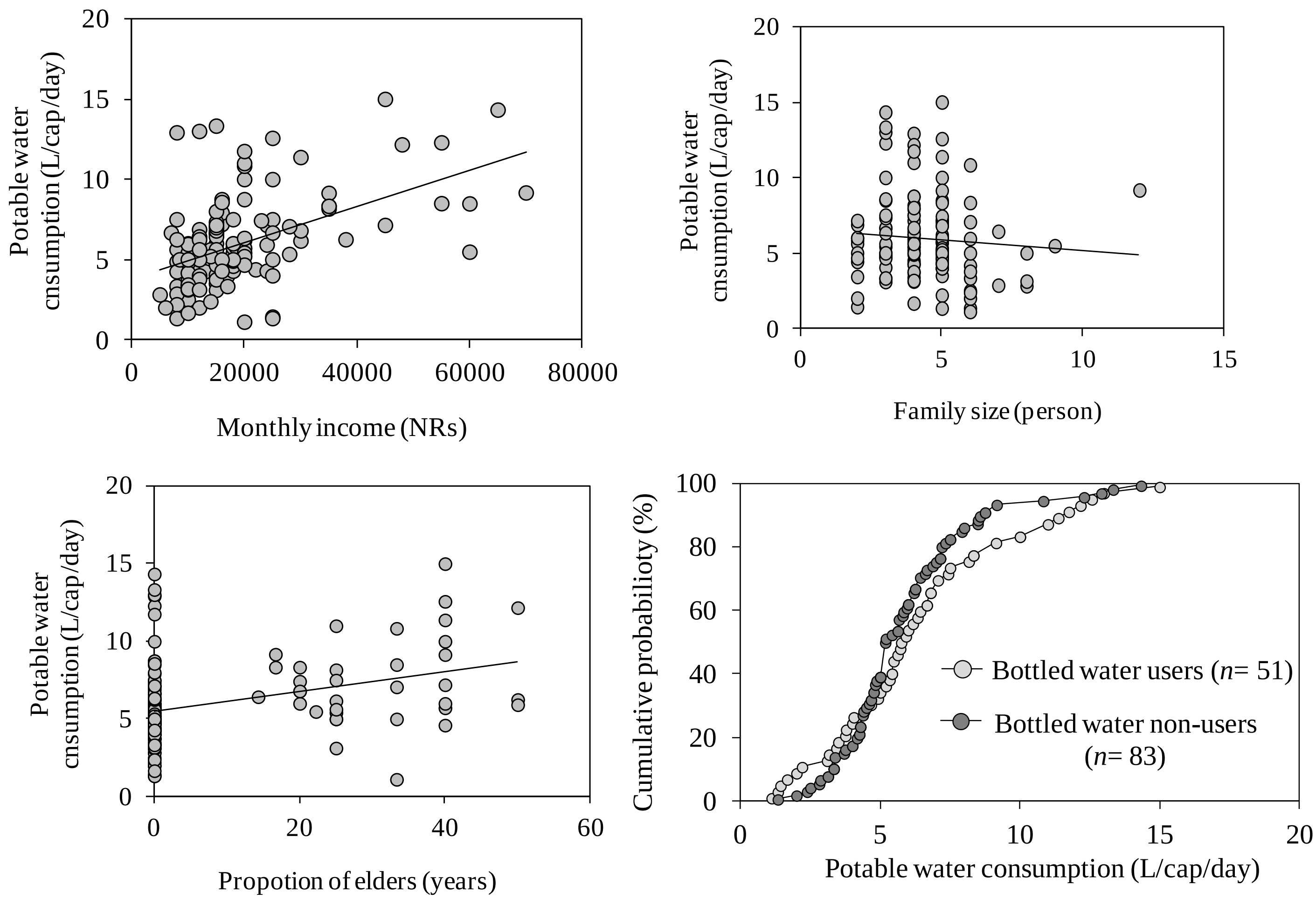
VII (E) Water conservation practices at household level

Respondent no.	Use grey water for toilet	Use grey water for garden	Use rainwater	Use multiple sources	Reduce no. of bath/week	Reduce no. of laundry/week	Increase Storage size	Retrofit	Dig wells	Shift to new place
161	Y	N	Y	Y	N	N	N	N	N	N
162	N	Y	N	Y	N	N	N	N	N	N
163	N	Y	N	N	N	N	N	N	N	N
164	N	N	N	Y	Y	Y	N	N	N	N
165	N	Y	N	N	N	Y	N	N	N	N
166	N	N	N	N	N	Y	N	N	N	N
167	N	N	Y	Y	N	N	N	N	N	N
168	N	N	Y	Y	Y	Y	Y	N	N	N
169	N	N	Y	N	Y	Y	N	N	N	N
170	N	N	N	N	Y	Y	N	N	N	N
171	N	N	Y	Y	Y	Y	N	N	N	Y
172	N	Y	Y	Y	Y	Y	Y	N	N	N
173	N	N	N	Y	N	N	N	N	N	Y
174	N	N	N	Y	Y	Y	N	N	N	N
175	Y	Y	N	Y	Y	Y	Y	N	N	Y
176	Y	Y	N	Y	Y	N	N	N	N	N
177	N	N	Y	Y	N	N	N	N	Y	N
178	N	N	N	Y	N	N	Y	N	Y	N
179	Y	Y	N	Y	N	N	N	N	N	N
180	N	N	N	Y	N	N	Y	N	Y	N
181	N	N	Y	Y	N	N	N	N	N	N
182	Y	N	Y	Y	N	N	Y	N	Y	N
183	N	Y	Y	Y	N	N	Y	N	N	N
184	Y	N	Y	Y	N	Y	N	N	Y	N
185	N	N	Y	Y	Y	Y	N	N	N	N
186	N	N	Y	Y	N	Y	N	N	N	N
187	N	N	N	Y	N	N	N	N	N	N
188	Y	N	Y	Y	N	N	Y	N	N	N
189	N	N	N	Y	N	N	Y	N	Y	N
190	N	N	N	Y	N	N	N	N	N	N
191	N	Y	Y	Y	N	N	N	N	N	N
192	Y	N	N	N	N	Y	Y	N	N	N
193	N	Y	Y	Y	Y	Y	N	N	N	N
194	N	N	N	N	Y	Y	N	N	N	N
195	N	Y	Y	Y	N	N	N	N	N	N
196	N	N	N	Y	Y	Y	N	N	N	N
197	N	N	Y	Y	N	N	N	N	Y	N
198	N	N	N	Y	Y	Y	N	N	N	N
199	N	N	N	Y	Y	Y	N	N	N	N
200	N	Y	N	Y	N	N	N	N	N	N

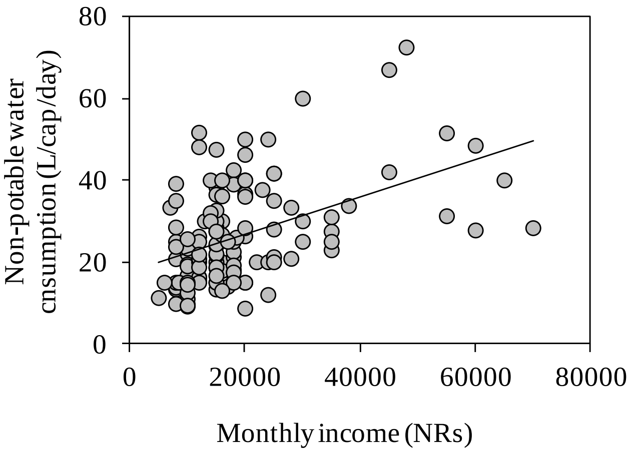
VII (F) Water conservation practices at household level

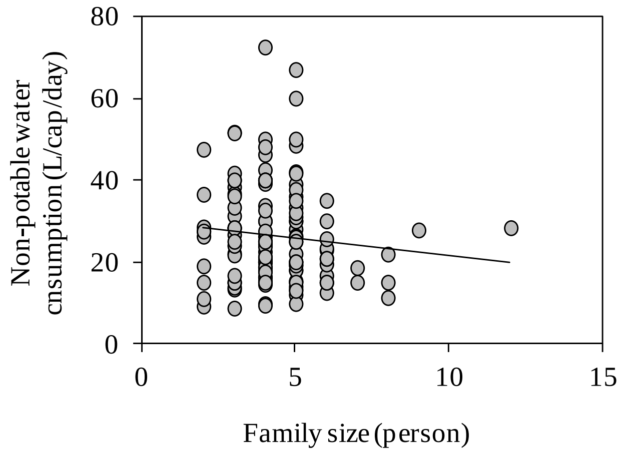
Respondent no.	Use grey water for toilet	Use grey water for garden	Use rainwater	Use multiple sources	Reduce no. of bath/week	Reduce no. of laundry/week	Increase Storage size	Retrofit	Dig wells	Shift to new place
201	N	N	N	Y	N	N	N	N	N	N
202	N	N	N	N	Y	Y	N	N	N	N
203	Y	N	Y	Y	N	N	N	N	N	N
204	N	N	Y	N	Y	Y	N	N	N	N
205	N	N	Y	N	N	N	N	N	N	N
206	N	N	Y	Y	Y	Y	N	N	N	N
207	N	N	N	Y	N	N	N	N	Y	N
208	N	N	N	Y	N	N	N	N	N	N
209	N	N	N	Y	Y	Y	Y	N	Y	N
210	N	N	N	Y	N	N	N	N	N	N
211	N	Y	Y	Y	Y	Y	Y	N	N	N
212	Y	N	N	Y	N	N	N	N	N	N
213	N	N	N	Y	N	N	N	N	N	N
214	N	N	N	Y	N	N	N	N	N	Y
215	N	N	N	Y	N	Y	N	N	N	N
216	N	N	N	Y	Y	Y	N	N	N	Y
217	N	N	N	Y	N	N	N	N	Y	N

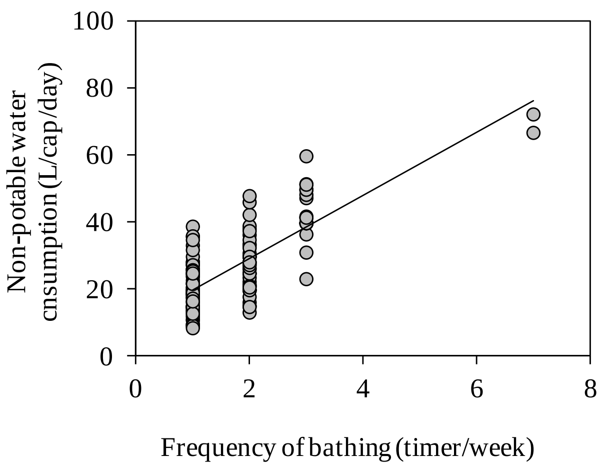
Appendix VIII Relationship between potable water consumption and its predictors

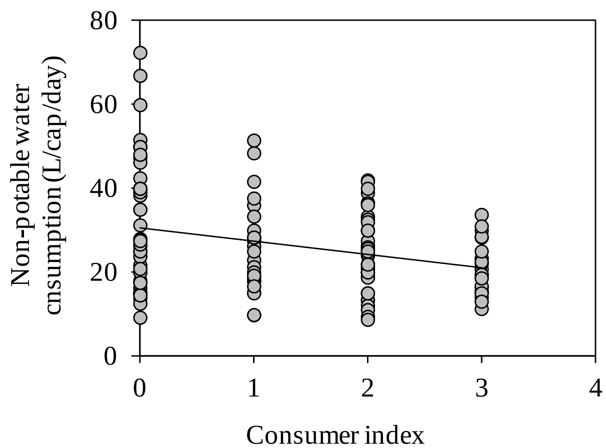


Appendix IX Relationship between non-potable water consumption and its predictors









Appendix X (A) Microbial water quality data for Private pipe connection

Points of water collection									
Total coliform count (CFU/100mL)					*E. coli* count (CFU/100mL)				
Source	Non-potable storage	Potable storage	Treated at house	Post-treatment	Source	Non-potable storage	Potable storage	Treated at house	Post-treatment
37.0	190.0	79.3	6.8	16.0	1.7	2.7	1.7	0.2	0.2
37.0	167.7	67.3	8.2	23.3	1.7	2.0	1.7	0.3	0.7
37.0	73.3	53.7	8.2	23.0	1.7	0.7	1.7	0.2	0.7
13.0	22.7	10.7	0.7	-	0.7	3.0	0.7	0.1	-
13.0	46.7	19.3	8.6	-	0.7	0.3	0.0	0.2	-
13.0	45.0	55.3	7.6	7.2	0.7	0.7	1.0	0.1	0.6
38.3	-	66.7	3.0	-	2.0		1.0	0.1	-
38.3	62.7	43.7	0.5	4.7	2.0	2.0	1.7	0.2	0.3
38.3	138.0	99.3	3.7	-	2.0	2.0	1.0	0.3	-
38.3	224.7	126.3	3.7	-	2.0	3.0	5.7	0.3	-
13.0	-	22.3	2.0	-	0.7		0.3	0.0	-
13.0	439.3	57.0	5.4	-	0.7	12.7	0.7	0.1	-
13.0	123.3	18.3	0.4	-	0.7	6.7	1.0	0.0	-
13.0	215.3	34.3	2.3	-	0.7	2.0	0.7	0.1	-
6.7	-	5.3	0.8	-	1.7		1.7	0.2	-
6.7	-	32.0	0.4	-	1.7		2.0	0.1	-
2.3	87.0	11.3	2.7	-	0.0	9.3	3.7	0.6	-
2.3	119.0	31.3	0.4	9.1	0.0	13.7	2.3	0.0	0.2
85.3	144.7	94.0	8.8	-	4.7	5.0	8.0	0.5	-
85.3	138.7	77.7	2.3	-	4.7	4.7	2.7	0.0	-
12.7	18.0	21.7	1.5	9.0	1.0	0.3	0.7	0.1	0.1
85.3	144.7	94.0	8.8	-	4.7	4.7	4.3	0.5	-
83.7	138.7	77.7	2.3	-	4.7	4.7	2.7	0.0	-

Appendix X (B) Microbial water quality data of Tanker

Points of water collection									
Total coliform count (CFU/100 mL)					*E. coli* count (CFU/100 mL)				
Source	Underground tank	Overhead tank	Treated at house	Post-treatment	Source	Underground tank	Overhead tank	Treated at house	Post-treatment
24.3	144.0	88.0	2.3	6.7	2.0	21.3	17.7	0.1	0.3
76.0	176.7	152.3	1.2	-	1.0	3.0	1.0	0.2	-
120.3	230.3	199.0	0.5	-	2.0	2.0	2.0	0.1	-
85.3	52.3	15.3	3.5	-	2.0	1.7	1.3	0.1	-
63.7	56.0	73.3	12.3	16.3	7.3	4.3	3.3	0.5	-
10.3	13.0	24.7	8.3	-	0.3	0.0	2.7	0.1	-
122.7	266.0	147.7	21.5	-	0.0	1.7	1.3	0.1	-
220.3	246.7	145.7	2.4	-	23.0	23.3	17.3	0.1	-
123.7	76.7	13.3	0.3	2.7	5.0	0.0	1.7	0.0	-
92.3	116.7	94.0	2.9	-	0.7	13.3	15.0	0.0	-
20.3	18.3	29.0	6.7	-	0.3	1.0	0.7	0.0	-
120.3	125.0	127.0	59.0	-	2.3	2.0	1.3	0.0	-
136.0	91.0	89.3	7.7	-	4.7	2.7	2.3	0.5	-
22.0	73.0	58.7	4.0	-	3.0	5.0	3.0	0.1	-
63.7	60.3	61.7	13.0	-	6.0	4.3	5.3	0.9	-
130.3	188.3	153.3	59.3	-	12.7	3.3	4.3	1.1	-
206.7	316.0	173.3	64.0	-	16.7	44.3	8.7	1.0	-

Appendix X (C) Microbial water quality data for Vendor

Points of water collection									
Total coliform count (CFU/100mL)					*E. coli* count (CFU/100mL)				
Source	Non-potable storage	Potable storage	Treated at house	Post-treatment	Source	Non-potable storage	Potable storage	Treated at house	Post-treatment
6.7	6.3	85.3	8.8	7.3	1.0	0.7	6.7	0.0	0.1
6.7	28.3	150.7	6.2	-	1.0	2.0	15.0	0.1	-
17.7	24.0	-	17.4	48.3	1.3	2.0	-	0.1	0.0
17.7	72.0	-	16.1	-	1.3	2.0	-	0.2	-
73.3	230.7	655.3	75.3	116.7	3.3	12.7	30.0	1.3	2.0
73.3	111.7	179.0	20.3	19.7	3.3	2.3	13.7	0.8	1.0
132.0	144.3	156.0	20.3	-	6.3	4.3	3.7	1.1	-
132.0	116.3	116.3	45.0	-	6.3	5.7	11.0	1.1	-
132.0	156.7	170.0	25.7	25.0	6.3	7.3	10.7	0.1	0.1
38.7	48.7	123.0	0.8	-	1.7	1.7	3.7	0.0	-
38.7	34.7	48.3	0.1	-	1.7	1.7	1.7	0.0	-
16.0	61.3	228.0	-	-	1.3	4.3	19.3	-	-
16.0	86.7	396.7	-	-	1.3	5.3	31.7	-	-
16.0	104.7	322.0	-	-	1.3	8.3	18.7	-	-
16.0	53.0	346.7	-	-	1.3	5.3	21.3	-	-
16.0	101.7	176.3	5.3	-	1.3	5.3	6.7	0.7	-
16.0	108.7	145.0	2.2	-	1.3	6.7	25.0	0.2	-
81.0	126.7	179.0	-	-	5.7	11.7	19.3	-	-
81.0	98.7	129.3	-	-	5.7	6.3	10.0	-	-
81.0	139.0	202.3	-	-	5.7	12.0	16.3	-	-
81.0	144.7	273.0	-	-	5.7	13.0	31.0	-	-

Appendix X (D) Microbial water quality data for Stone spout

Points of water collection					
Total coliform count (CFU/100 mL)			*E. coli* count (CFU/100 mL)		
Source	Non-potable storage	Potable storage	Source	Non-potable storage	Potable storage
2473.3	2673.3	2960.0	86.7	93.3	146.7
2473.3	2553.3	2640.0	86.7	80.0	126.7
2473.3	2900.0	3040.0	86.7	113.3	133.3
2473.3	2540.0	2686.7	86.7	86.7	140.0
2473.3	2613.3	3313.3	86.7	86.7	120.0
3026.7	3606.7	3846.7	6.7	26.7	46.7
3026.7	3360.0	4380.0	6.7	20.0	93.3
3026.7	3120.0	4060.0	6.7	13.3	66.7
2253.3	2286.7	3300.0	20.0	13.3	106.7
2253.3	2420.0	2540.0	20.0	66.7	100.0
2253.3	2326.7	4360.0	20.0	53.3	140.0
1666.7	1700.0	2380.0	13.3	33.3	80.0
1666.7	1986.7	2100.0	13.3	20.0	53.3
1666.7	1746.7	2580.0	13.3	13.3	33.3
2273.3	2520.0	2906.7	106.7	133.3	160.0
2273.3	2306.7	2533.3	106.7	113.3	113.3
2273.3	2400.0	3293.3	106.7	100.0	133.3

Appendix XI Pictures of field work

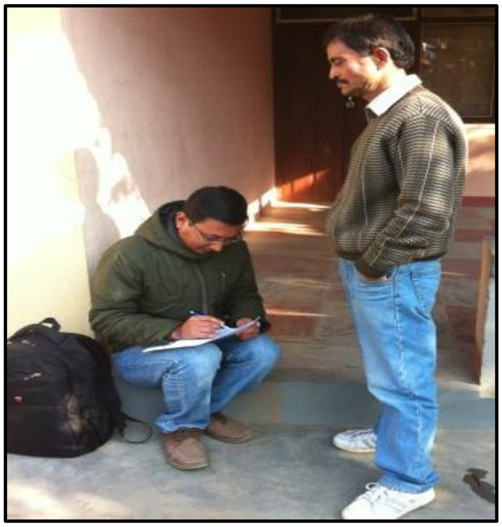


Photo 1: Interview survey

Photo 2: Water consumption survey

Photo 3: Stone spouts

Photo 4: Tanker

Photo 5: Water quality survey

Photo 6: Portable water storage containers